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EXPERIMENTS

ON

WROUGHT-IRON AND STEEL.

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RESULTS

OF

AN EXPERIMENTAL INQUIRY

INTO THE

TENSILE STRENGTH AND OTHER PROPERTIES

OF VARIOUS KINDS OF

WROUGHT-IRON AND STEEL.

BY

DAVID KIRKALDY.

ILLUSTRATED BY NUMEROUS PLATES AND DIAGRAMS.

Second Edition.

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PREFACE.

THE circumstances leading to the experimental inquiry of which the following treatise forms the record, may be briefly stated as follows:—

Messrs. Robert Napier & Sons having received orders for some high-pressure boilers and marine machinery, where lightness combined with strength was of the utmost importance, it was proposed to use "homogeneous-metal" for the one and "puddled-steel" for the other, instead of wrought-iron as ordinarily employed. As these materials, however, had then been only recently introduced, it was considered prudent, before employing them, to ascertain their relative merits; and with this view the apparatus, to be described afterwards, was erected. At the time it was only intended to test a few specimens of each, but the investigation proved both so interesting in itself and so likely to conduce to important practical results, that I was induced, under the sanction of Messrs. Napier, to extend the experiments, as leisure and opportunity offered, very considerably beyond what had been originally contemplated. The testing was commenced on 13th April, 1858, and terminated 18th September, 1861, during which time the same apparatus was employed by me in testing for Messrs. Napier the strength of the iron plates and angle-iron to be used in the construction of H. M. armour-cased ships "Black Prince" and "Hector."

The results of some of these experiments were sent by Messrs. Napier to the Institution of Engineers in Scotland, and were published in 1859 in the second volume of its Transactions. The Tables were accompanied by illustrative Plates (the first four of the present series) and a few explanatory remarks, but without any direct expression of opinion, as it was then considered advisable merely to present the numerical results, and leave every one to draw his own conclusions.

The Scottish Shipbuilders' Association having expressed their wish that I should furnish it with an account of my experiments, and the conclusions at which I had arrived, a paper was, accordingly, with the concurrence of Messrs. Napier, drawn up by me, and was read before the Association at its meeting in April last year. As the time allowed for its preparation was necessarily limited, and as many of the calculations and experiments hereafter tabulated were then still in progress, it was agreed that no discussion should take place until the whole subject was fairly completed. Although a much longer time has elapsed than I could have wished, between the reading of the above paper and the publication of the present essay, I trust that a due allowance will be made for the importance of the subject and the amount of work to be performed.

The experiments were made for, and in the Works of, Messrs. Napier, but the entire management was left to myself, to act as I considered to be for the best advantage. It may also be stated, that I received no assistance whatever in carrying out these experiments. The specimens were all collected and registered, the results of the testing noted, and the whole of the calculations worked out by myself, so that I alone am responsible for their accuracy. During the last six months, since leaving Messrs. Napier, in whose employment I was for nineteen years, I have been enabled to devote a much larger share of attention to the subject than I could formerly bestow on it, when I was engaged with other duties.

Whilst stating my own conclusions, derived wholly from experiments personally instituted by me, I considered it desirable to adduce, at the same time, the opinions entertained by others. Wishing to do so as fairly as possible, I deemed it advisable to quote their own words rather than attempt to express their views myself, which might have exposed me to the charge of misconstruction. These quotations have been carefully extracted and the source duly acknowledged. Reference has also been made to all the previous experiments that I could find bearing on the present question.

It has been my anxious endeavour, throughout the whole of this investigation, to pursue it with candour and impartiality, and to present to those interested in such matters a plain statement of the facts elicited. I have striven to avoid drawing anything like unjustifiable inferences or deductions, and have confined myself strictly to such conclusions as I believe to be fully warranted by the experiments. The data on which these are based being all minutely stated, it will be in the power of every one to judge for himself of their correctness.

To the President and Council of the Institution of Engineers in Scotland I have to express my thanks for their kindness in presenting me with the stereotyped portion of the Tables originally published in their Transactions, and now forming the first series of Tabulated Results in the following treatise. The second series of Tables is entirely new, and now published for the first time.

DAVID KIRKALDY.

4 CORUNNA STREET,
GLASGOW, *15th July, 1862.*

PREFATORY NOTE TO THE SECOND EDITION.

In printing a second thousand copies of this work, I embrace the opportunity it offers to express the satisfaction which I feel that my earnest endeavours to supply reliable data have been so fully appreciated by Civil, Mechanical, and Mining Engineers, Iron and Steel Makers, Merchants, and Shipowners throughout the country. In the List of Subscribers now appended will be found the names of many of the principal firms in the various departments of Iron Manufacture and Engineering, and of many individuals who hold the most prominent places among scientific and constructive Engineers.

On 26th November last I submitted to the Institution of Engineers in Scotland a paper containing the various conclusions which I have deduced from my experiments, and exhibited an extensive series of the fractured and other specimens produced in course of my investigations. These conclusions are embodied in this work, and a full report of the lengthened discussion that took place at that and the following meeting will be found in the Society's published Proceedings. The specimens were also exhibited to the Scottish Shipbuilders' Association on 1st December last, and in the Appendix (M) there is inserted a copy of a letter read at the meeting of the Association on 5th January, and a report of the discussion that followed.

I shall always cherish in grateful remembrance the many acts of personal kindness bestowed upon me, and the many encouraging letters received in connection with this work.

David Kirkaldy.

4 Corunna Street,
Glasgow, *12th June, 1863.*

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EXPERIMENTS

ON

WROUGHT-IRON AND STEEL.

Preliminary Remarks.

1. In response to the expressed wish of this Association,* that he should give some explanations relative to these experiments, and the conclusions arrived at, the writer proceeds to give a detailed account of the whole process and results, that all may judge for themselves. Having frequently experienced disappointment when examining experiments on various interesting subjects, from many particulars necessary for their fair consideration being withheld, intentionally or otherwise, he resolved, should ever an opportunity occur, to avoid that error; and in now endeavouring to do so, he may by some be considered to have given more details than are required. He has anxiously endeavoured to arrange in a series of tables the mass of collected and calculated data in as compact a form as seemed practicable, in order to facilitate comparison of the various results, and also with the view of enabling those who may choose to consult them to select the material best suited for their particular purpose.

2. It seems remarkable that whilst we have the results of many important and reliable experiments on Cast-iron, extremely few have been made, or at least published, on Wrought-iron, and almost none on Steel. Although much has been said and written on the subject of wrought-iron and steel, yet, such is the great diversity of opinions held and stated by different individuals, that it is hoped the results of these experiments, intended simply to elicit the truth, will be considered worthy of examination by those interested, and also at the same time prove of practical utility. Believing that the collection and methodical arrangement of carefully ascertained data is the best and only certain way of arriving at right conclusions,

---

* See Preface.

this opportunity was eagerly embraced of obtaining facts by direct experiment, and that with as many varieties of each as could be obtained.

3. Although the present inquiry has been confined to the effects produced from Tension strains alone, the field is nevertheless an extensive one, as will at once be apparent when we consider the many kinds of iron-ore used, the different methods of converting it—on the one hand into steel, and on the other into wrought-iron, and also the difference in the fuel employed.

4. In these experiments, whilst ascertaining the exact amount of strain required to tear the pieces asunder, in order to know and compare their different tenacities or ultimate strengths, it was considered of no less importance to observe and note many other particulars, as likely to disclose their various peculiarities. It was necessary to test several pieces in each lot, to obtain an average, and these had all to be broken in precisely the same manner.

5. With the view of still further developing any other properties, and also to find the effects produced, if any, by subjecting the specimens to various kinds of treatment, other pieces were taken from the *same* bars and plates as the previous set, and similarly broken, whilst in some the effects of altering the specimen's shape were also ascertained.

6. Pieces were likewise taken and screwed, to ascertain how much the strength was reduced, or the ratio that a screwed bolt bore to the original bar; whilst other pieces were cut asunder and then welded, to find the relative strength of welded joints.

7. The strain in all these cases was *gradually* increased until rupture took place; but with another set of specimens, also taken from the same bars, the strain was *suddenly* applied.

8. Remarks, and the various conclusions come to, will be given under the following sections, viz.:—

I. Mode of collecting specimens.
II. Description of testing apparatus.
III. Preparation of specimens.
IV. Classification of experiments.
V. Mode of conducting experiments.
VI. Method of calculating and tabulating detailed results.
VII. Tabulated summary of results.
VIII. Breaking weight and contraction of area—Iron.
IX. Do. do. do. do. Steel.
X. Appearance of fractures—Iron.
XI. Do. do. Steel.

XII. Rate of elongation under increasing strains.
XIII. Influence of various kinds of treatment.
XIV. Effects of altering shape of specimen.
XV. Comparative strength of screwed and chased bolts.
XVI. Relative strength of welded joints.
XVII. Suddenly applied strains.
XVIII. Specific gravities.
XIX. Concluding observations.

I. MODE OF COLLECTING SPECIMENS.

9. For the Government "Experiments on Cast-Iron for Cannon," the producers were invited to send in samples, but for the present inquiry it was considered decidedly preferable to take the specimens that were to be tested from bars and plates as produced for the market, instead of applying to the various makers for samples, which might or might not be superior to those usually turned out. It is therefore to be understood that all the specimens tested were indiscriminately collected from engineers' or merchants' stores, except those marked *samples*, which were obtained from the makers, owing to their not being found in stock at the time. In some instances, however, specimens of the same make were afterwards obtained from stores, and consequently both sets appear in the accompanying tables.

10. An attempt was made to suppress the publication of the first portion of these experiments, under the plea that the pieces had not been procured directly for the purpose; but fortunately it was unsuccessful, and it is hardly necessary to mention that the threatened *legal proceedings* have not *yet* commenced.

11. The trial specimens were severally cut from four or more different bars or plates, to obtain an average, whilst from each plate a piece was cut off lengthways, and another crossways, and correspondingly marked L and C. All the trial specimens were duly registered, when, and from whom received, and were distinguished by numbers or marks.

12. Nothing was taken as to the origin of which the least doubt existed; and, with very few exceptions, the plates and bars bore the makers' brands. In many cases, the makers' names or brands were concealed from the experimenter, at his own request, until after the specimens were tested and the results communicated to the parties from whom they were obtained; such specimens being sent with private marks for subsequent identification.

13. Although the quality of the specimens, in too many instances, was greatly inferior to that indicated by the brand, there are many others in the tables in which the two corresponded, and in a few the quality was superior.

II. DESCRIPTION OF TESTING APPARATUS.

14. The apparatus employed was of the simplest construction, and proved during the experiments to work most satisfactorily. It is fully delineated in Plate I.; fig. 1, being a longitudinal sectional elevation of the entire arrangements; fig. 2, a corresponding end elevation; and figs. 3 to 6, representing details drawn on a larger scale. A large cast-iron base-plate, A, resting on wooden sleepers, *b*, forms a rigid foundation for the two upright standards, C, which support the cross bar, *d*, passing through the eyebolt, *e*, of the large wrought-iron steelyard, F. Shackles, *g*, connect the steelyard's eyebolt, *h*, to the specimen, *k*, to be tested; the lower end of the specimen being connected by the shackles, *g'*, to the adjusting screw, *l*, which works in a nut fastened to the underside of the foundation plate, A. A platform, M, supports the men who apply the weights, N, by separate hooks to chains hanging from the end of the steelyard, F. An adjustable platform, O, receives the falling weights, whilst the block, P, sustains the steelyard, when it drops at the breaking of the specimen. A rope-sling, *r*, attached to the chain-hook of a derrick crane, is employed for elevating the steelyard into the position indicated by dotted lines, at the commencement of each experiment; the amount of elevation varying with the specimen to be tested.

III. PREPARATION OF SPECIMENS.

15. The necks of the bolts were slightly tapered, as shown in fig. 5, to insure the fracture taking place somewhere in the central part or body of the bolt, instead of at the neck or shoulder; the heads of the iron bolts were formed by welding on rings, and those of the steel by staving down the solid bar. Several attempts were made to weld rings on the latter; but, in most instances, the rings failed at the trial, and consequently other specimens had to be substituted. Figs. 3 and 4 represent the forms of the plate specimens; the thinner plates tested having side pieces rivetted on, as shown in fig. 4, to give longer bearings to the steel pins, whilst the plates, fig. 3, of a thickness of four-tenths and upwards did not

require any. Fig. 5 exhibits the form of the bar specimens with full details of their receiving shackles, three different sets being used to suit the various sizes tested. Fig. 6 refers to the screw bolt-and-nut experiments. Marks were made with a centre-punch for receiving the points of a large pair of compasses, and used for measuring the gradual elongation of the specimens, as the weights were applied to the steelyard, as shown in the various figures. In order to ascertain the length of the part stretched, a number of specimens had the distance between the punch marks divided into half-inch spaces previous to applying the weights as in Plate XIV.

16. In order that the series might be strictly comparative, care was taken that, as far as was possible, all the specimens should be similarly prepared, or when otherwise, the difference stated. On referring to the accompanying Tables, **A** and **B**, in the description column will be found the terms "rolled bars," signifying that the central portion, or part to be drawn asunder, had not been operated upon by the smith; "forged," that they were reduced to the given size by the smith; and "planed," that the rolled bar had been reduced in the planing machine, to find if its relative strength was thereby affected; whilst other pieces are noted as "turned" down in the lathe for a similar purpose.

17. Various sizes of bars were taken, to ascertain if the relative strength increased as the bars decreased in diameter; also square and round bars, to find if they corresponded per square inch of section.

IV. CLASSIFICATION OF EXPERIMENTS.

18. The results of these experiments are given in a series of twenty tables, distinguished by the letters **A**, **B**, &c., and sixteen illustrative plates, grouped and arranged as follows:—

TABLES.

	Breaking Weight, Contraction of Area, Elongation, and Characteristics of Fracture.		Rate of Elongation.		Effects of Difference in the		Screwed and Chased Bolts.		Welded Joints.	Sudden Strains.	Specific Gravities
	Detail.	Summary.	Observed.	Reduced.	Treatment.	Shape.	Details.	Summary.			
Bars, .. Steel,	A	F	L	M	N, O	P	Q	R	S	T	U
Iron,	B	G									
Plates, Steel,	C	H									
Iron,	D	J									
Beam, Strap, & Angle-Iron,	E	K									

ILLUSTRATIVE PLATES.

Testing Apparatus, &c.—I.

	Fractures for Tables A, B, C, D, E, N.	Diagrams for Tables F, G, H, J, K.	Diagrams for Table M.	Fractures, &c., for Tables		
				B. C. D.	P.	Q. T.
Bars, .. Steel,	II.	VI.	XI.,XII.,XIII.	XIV.	XV.	XVI.
Bars, .. Iron,	II., V.	VII., VIII.				
Plates, Steel,	III.	VI.				
Plates, Iron,	IV.	IX.				
Beam, Strap & Angle-Iron,	IV., V.	X.				

19. The following list of specimens experimented upon does not include those used in the many preliminary trials made in order to ascertain the accuracy of the apparatus, the most suitable method of conducting the experiments, the size and form of specimens, mode of applying the weights, &c.; neither does it include any of those specimens that could not with fairness be given, and which were subjected to fresh trials on account of casual defects in their preparation, &c. Also in cases where there occurred a great dissimilarity in one of the pieces forming a lot, another piece from the same bar or plate was tested in confirmation, and of course only the result of one could equitably be given in the tables:—

90	Steel bars,............................	Table	A,	index numbers,	1 to 90
810	Iron bars, ...	”	B	” ”	101 ” 300 701 ” 810
80	Steel plates, ...	”	C	” ”	801 ” 880
329	Iron plates,..........................	”	D	” ”	401 ” 600 851 ” 979
72	Angle-iron, &c.,.....................	”	E	” ”	601 ” 672
44	Steel bars, Treated variously,....	”	N	” ”	1001 ” 1044
76	Iron bars, do. do., ...	”	N	” ”	1045 ” 1120
20	Iron plates, do. do., ...	”	O	” ”	1121 ” 1140
24	Steel plates, do. do., ...	”	O	” ”	1141 ” 1164
14	Steel plates, Rivetted joints, ...	”	O	” ”	1165 ” 1178
44	Iron bars, Shaped variously,......	”	P	” ”	1201 ” 1244
180	Iron bars, Screwed, chased,.......	”	Q	” ”	1301 ” 1480
18	Iron bars, Welded joints,..........	”	S	” ”	1481 ” 1498
2	Steel bars, do. do., ...	”	S	” ”	1499 ” 1500
50	Iron bars, Suddenly applied strains,	”	T	” ”	1501 ” 1550

Total, 1353 specimens tested by Machine.
Total, 165 specimens tested by Specific gravity.
Total, 286 specimens tested by Muriatic acid.

93	Iron bars, Specific gravity,.......	Table	U	index numbers,	1601 to 1693
10	Angle-iron, do. do., ...	”	U	” ”	1694 ” 1703
30	Iron plates, do. do., ...	”	U	” ”	1704 ” 1733
16	Steel plates, do. do., ...	”	U	” ”	1734 ” 1749
16	Steel bars, do. do., ...	”	U	” ”	1750 ” 1765

Summary of results,	Steel bars,…………	Table	F,	*reference*	numbers,	1	to	18
Do. Do.,	Steel plates,……….	„	H	„	„	51	„	72
Do. Do.,	Iron bars,…………	„	G	„	„	101	„	180
Do. Do.,	Iron plates,………..	„	I	„	„	201	„	253
Do. Do.,	Angle-iron, &c., ….	„	K	„	„	271	„	288
Rate of elongation,	Observed,………….	„	L	„	„	301	„	470
Do. Do.,	Reduced, ………….	„	N	„	„	501	„	590
Summary of results,	Screwed bolts,…….	„	R	„	„	601	„	628

20. In these tables the strains are all stated in lbs., but Table V is added to facilitate their conversion into tons by those who may wish to effect it.

V. MODE OF CONDUCTING EXPERIMENTS.

21. Each bolt, with the bearing part of its heads turned true in the lathe, was first carefully gauged, and the distance between the inside edges of the heads measured by an accurately-divided ivory scale, and the same duly recorded. The bolt was then fastened in the shackles and placed in position, the steelyard having been raised to the required elevation by means of the crane. The connection having been completed by means of two steel pins, the crane chain and sling were lowered so as to clear the steelyard, and the attendants applied the weights in succession, beginning with weights of 56 lbs., and gradually reducing to weights of 28 lbs., 14 lbs., 7 lbs., 4 lbs., as the breaking point was approached. The descent of the steelyard was observed by sighting it with the brick-work of a neighbouring wall; additional weights were not applied until the motion caused by the preceding weights ceased to be apparent.

22. In the hard, brittle, and coarser kinds of Iron little or no indication was given of the approaching rupture, by the gradual descent of the steelyard; on the contrary, it dropped suddenly on the breaking of the specimen. This remark also applies to the hard classes of Steel. In such cases the lighter were repeatedly changed for heavier weights, until the limit of the specimen's tenacity was reached.

VI. METHOD OF CALCULATING AND TABULATING DETAILED RESULTS.

23. The specimens are distinguished by index numbers placed in the first column of each Table, and to avoid confusion no index number is repeated. In "Table A—Steel Bars," and "Table B—Iron Bars," column 3 records for each experiment the total weight on the steelyard at the time it dropped. This is multiplied by 28, leverage of steelyard, and there is added to the product the weight required to

counterbalance the steelyard, namely, 9,142 lbs., less 72 lbs. weight of the two upper shackles with their pins, or 9,070 lbs., the net weight. Thus, for example, when specimen No. 1, Table **A**, broke, there were on the steelyard eleven 56 lb., five 28 lb., and two 14 lb. weights, = 784 lbs., making, with 38 lbs. weight of attaching hooks and chain, 822 lbs., as stated in column 3; and 822 lbs. x 28 leverage of steelyard = 23,016 lbs., making, with 9,070 lbs. for steelyard, 32,086 lbs., which, being divided by the area of the specimen, ·2207 (column 2), gave 145,383 lbs. (column 4) as the breaking weight of that specimen per square inch of its *original* sectional area.

24. The bars contracting more or less, according to the quality or peculiarities of the Steel and Iron tested, it was considered both interesting and important to present these results in a tabular form. Accordingly, columns 6 and 12 contain, respectively, the sizes resulting from the general *stretching* of the bolts and that at the *fractures;* columns 7 and 13 give the corresponding areas, and columns 8 and 14 the differences between these and the *original* areas. The mean differences of the various lots are given in columns 9 and 15; and in columns 10 and 16 the per centages of the same; whilst the results of dividing by the *stretched* and *fractured*, instead of by the *original* areas, are given in columns 11 and 17.

25. The total elongation of each specimen was found by noting the length (between the insides of the heads) previous to submitting it to the test, and deducting that from the length, again measured by placing the two broken pieces as close together as the nature of the fracture would admit (allowance being made for any intervening space). This difference is entered in column 18 of the Tables; original length in column 10; mean difference or elongation in inches in column 19; and per centage in column 21.

26. Characteristics of the fracture are attempted to be given in columns 22, 23, and 24; column 24 referring to the accompanying illustrations, Plates II., III., IV., and V. The particular specimen selected for illustration, as the representative of its class, is distinguished in the Tables by a heavy letter, as **A**; the others grouped under that class having a lighter letter, as A. When two letters are used, it signifies that the specimen presents mixed features. Column 22 indicates whether the fracture is wholly fibrous or not; in Table **A**—Steel bars, "100" signifies that the fracture is entirely of a fine granular semi-lustrous appearance; "0," that it is wholly of a silky fibrous lustre; whilst in Table **B**, "0" indicates that the Iron is entirely fibrous, and, "100," that it is wholly crystalline, of a bright shining lustre. Intermediate numbers indicate intermediate qualities,

but only approximately. The general colour of the Iron and nature of its fibre are given in column 23.

27. The results are similarly recorded in Table C—Steel Plates; Table D—Iron Plates; Table E—Beam, Strap, and Angle-Iron. They contain, however, no reference to the *stretched* dimensions, owing to the circumstance that these were not so distinguishable from the original and fractured sizes as was generally the case in the bar specimens.

VII. TABULATED SUMMARY OF RESULTS.

28. The principal results contained in the preceding Tables are given in a condensed form in Tables F, G, H, J, K. Breaking weight per square inch of *original* area, in columns 1, 2, 3; per square inch of *fractured* area, column 6; Contraction of area at fracture, in per centage of original area, column 9; Elongation in per centage of original length, column 11; Characteristics of fracture, column 13. Columns 1 and 2 contain respectively the lowest and highest, and columns 3 to 13 the mean results. Columns *a* to *m*, contain figures denoting the relative positions of the various specimens under these separate heads. The various lots follow in the order of their ascertained quality, and the diversified results are linearly presented in Plates VI. to X.

VIII. BREAKING WEIGHT AND CONTRACTION OF AREA.—IRON.

29 Before proceeding with our remarks under this section, reference will be made to previous experiments on the tensile strength of wrought-iron, as referred to by various authors who have written on the Strength of Materials, &c.

30. Professor Robison, in the *Encyclopædia Britannica*, gives the results of Muschenbroeck's experiments on the breaking strength, per square inch, of various woods and metals,—"Iron bars, ordinary, 68,000; Stirian, 75,000; Best Swedish and Russian, 84,000; Horse-nails, 71,000. The last was an experiment to examine the vulgar notion that iron forged from old horse-nails was stronger than all others, and shows its falsity." The size of specimens was only $\frac{1}{25}$th of a square inch, and the results were published, according to Tredgold, in 1762.

31. Mr. Appleton, in his *Dictionary of Mechanics and Engineering* refers to some other experiments by Muschenbroeck,—German bar, 93,069, 85,900, 69,530, 69,133 61,361; Swedish, 88,972, 68,728; Liege, 82,839, 62,369; Spanish, 81,901; Oosement, 76,697, 68,728. Mean of 33 experiments on bars, by Perronnet, 61,041. Bar of the best quality, 66,000; bar of good quality, 55,000, by Rumford. Swedish

bar, reduced per hammer, 72,064; and English bar, reduced per hammer, 55,872, as ascertained by Rennie. Mr. Appleton observes,—"The *absolute* cohesion of malleable iron may be taken for square bars of different sizes as under; the resistance per square inch being proportioned to the breaking weight of the respective sizes. In bars ¼ inch square, resistance per square inch = 90,000 lbs.; ½ inch, 70,000; 1 inch and over, 56,000."

32. The *Engineer and Machinist's Assistant*, on the authority of Lamé, states, English bars at 25½ tons; Russian, 27 tons; Russian wire, 1-20th to 1-30th inch diameter, 60 to 91 tons; Swedish bars, per Rondelet, at 32 tons.

33. Mr. Tredgold remarks,—"The experiments on the absolute resistance of malleable iron to tension are very numerous; in many experiments it has been found above 80,000 lbs per square inch, and in very few under 50,000 lbs., indeed in none, where the iron is not defective."

34. Professor Barlow in his Essay gives the following nine experiments by Telford in 1814, at Brunton's works, expressed in tons and cwts.:—Welsh bars, 29"16, 29"5, 29"0; Staffordshire, 31"16, 31"0, 27"10, 27"3; Fagotted, 29"0; Swedish, 29"0; mean of the nine, 29"5⅔. Eight experiments by Captain S. Brown in 1817,—Welsh bar, 26·34, 26·33, 24·90, 24·35; Russian, 26·55; Swedish, 23·77, 23·75, 23·19; mean, 24·90. Then follows eight experiments by himself,—Solly's patent iron, 29¼, 26½, 26½, 25¾; mean, 27 tons; iron of good medium quality, 26, 25½, 25½, 24; mean, 25¼ tons. Twenty-six experiments by Sir Mark I. Brunel on Yorkshire iron reduced by hammer to ⅜ and ½ inch,—"best best" quality, mean of 10—32·3, varied from 36·4 to 29·6; "best" quality, mean of 10—30·4, varied from 34·6 to 25·0; another six of "best" quality, 30·8 from 32·75 to 27·0. Mr. Barlow remarks,—"The mean strength of these bars considerably exceeds that drawn from the preceding articles, a circumstance which may, it is presumed, be explained from the circumstance of their having been reduced per hammer." And lastly, ten experiments by Telford on iron wire give (Nos. 3 and 4, diameter $\frac{1}{10}$) 42·9; (2, ⅓), 42·0; (5 and 6, $\frac{1}{17}$), 38·1; (10, $\frac{1}{10}$), 36·1; (7, 8, 9, $\frac{1}{21}$), 35·8; (1, $\frac{1}{12}$), 35·7; mean, 38·4 tons per square inch. Mr. Barlow adds,—"Considerable discrepance will be observed between the strength of the wire in experiments 3, 4, and 10, which are of the same diameter. Perhaps a mean strength of 36 tons of a wire of less than, or not exceeding $\frac{1}{10}$th inch diameter, is all that can be depended upon."

35. Dr. Fairbairn, in his *Useful Information for Engineers*, and in his other writings, gives the results of his experiments, made in 1838, on

twenty pieces of plate; the strength appears by the following Table to be generally in favour of those torn asunder *across* the fibre, the mean of the whole being stated "as 22·5 : 23·0, equal to about $\frac{1}{45}$."

Quality of Plates.	Mean Breaking Weight in the direction of the fibre, in tons per square inch.	Mean Breaking Weight across the fibre, in tons per square inch.
Yorkshire plates, . .	25·770	27·490
Yorkshire plates, . .	22·760	26·037
Derbyshire plates, . .	21·680	18·650
Shropshire plates, . .	22·826	22·000
Staffordshire plates, . .	19·563	21·010
Mean, . . .	22·519	23·037

36. The same author, in his treatise on *Iron*, published 1861, makes no reference to the present series of experiments, although copies were sent to him of that portion which appeared December, 1859, in the *Transactions of the Institution of Engineers in Scotland*, but gives, in addition to the above table, the following tabulated "summary of the more recent experiments which I have made on the subject of the tensile strength of wrought-iron." It will be observed from this new table that the strength, with one exception, is in favour of those torn in the direction of the fibre, and not across, as in the former table.

Description of Iron.	Mean Breaking Weight, in tons per square inch.		Ultimate Elongation.
	With Fibre.	Across Fibre.	
Lowmoor iron (sp. grav. 7·6885), . .	28·661	23·433	...
Lancashire boiler plates (9 specimens), . .	21·815	20·096	$\frac{1}{25}$ and $\frac{1}{30}$
Staffordshire iron, ...	...	...	...
(Two $\frac{1}{4}$-inch plates riveted together) . .	21·357		...
Charcoal bar iron, ...	28·402	...	$\frac{1}{8}$
Best best Staffordshire charcoal plate (Mean of 4 experiments), ...	20·095	18·492	$\frac{1}{20}$ and $\frac{1}{22}$
Best best Staffordshire plates (Mean of 4 experiments), ...	22·297	20·745	$\frac{1}{20}$ and $\frac{1}{20}$
Best best Staffordshire plate, ...	26·706	24·474	$\frac{1}{16}$ and $\frac{1}{25}$
Best Staffordshire, ...	27·357	24·027	$\frac{1}{13}$ and $\frac{1}{22}$
Common Staffordshire, ...	22·688	23·582	$\frac{1}{20}$ and $\frac{1}{23}$
Lowmoor rivet iron (Mean of 2 experiments),	26·801	...	$\frac{1}{4}$
Staffordshire rivet iron, ...	26·563	...	$\frac{1}{4}$
Staffordshire rivet iron, ...	26·646	...	$\frac{1}{6}$
Bar of the same rolled cold, ...	37·956	...	$\frac{1}{12}$
Staffordshire bridge iron, ...	21·249	19·815	$\frac{1}{25}$ and $\frac{1}{35}$
Yorkshire bridge iron, ...	22·290	19·616	$\frac{1}{25}$ and $\frac{1}{28}$

37. Mr. Thomas Lloyd performed a series of experiments at Woolwich Dockyard, recorded by Dr. Fairbairn, to ascertain the effects of a tensile strain upon bars all of the same kind and size, namely, Staffordshire S C ❀, 1$\frac{3}{8}$ inch diameter, but under various condi-

tions. These will be again more particularly referred to under "elongation," Section XII. The medium breaking strains will, however, be given here. Effects of repeated breakage,— mean of 1st (10 trials), 23·94; 2d (10), 25·86; 3d (7), 27·06; 4th (6), 29·20. Dr. Fairbairn remarks,—"The results of the above experiments are highly interesting, as they not only confirm those previously made, but they indicate a progressive increase of strength, notwithstanding the reduced sectional area of the bars. These interesting facts are of considerable value, as they show that a severe tensile strain is not injurious to the bearing powers of wrought-iron, even when repeated to the extent of four times. In practice it may not be prudent to test bars and chains to their utmost limit of resistance; it is, however, satisfactory to know that in cases of emergency those limits may be approached, without incurring serious risk of injury to the ultimate strength of the material." In order to ascertain whether a shorter bar of iron was stronger than a longer one of the same kind and size, viz., 1⅝ inch, the following were tested:—6 pieces, 120 inches, broke with 32·21 tons; 6 pieces, 42 inches, 32·12; 6, 36 inches, 32·35; 6, 24 inches, 32·00; 6, 10 inches, 32·29. "As these experiments were made upon the same description of iron, it may be fairly inferred that the length of a bar does not in any way affect its strength."

38. Mr. Edwin Clark's magnificent work on the Britannia and Conway Tubular Bridges, contains the following table and remarks:—

No.	Description of Plate.	Breaking Weight per square inch.	Ultimate Extension in parts of the Length.
1	Plate 11/16th inch thick, neck 1½ inch long. Selected as bad iron, fracture bright and crystalline, brittle, broke readily with a blow from a hammer, ...	22	—
2	From the same plate, ...	21	1/40
3	Plate ½ inch, neck 6 inches. Selected as bad iron, containing two laminæ of crystalline metal, one-third of the whole section, .	18	1/160
4	Plate ½ inch, neck 5 inches. Selected as a good plate, about 1/10th of the section crystalline, .	19	1/48
5	Plate ½ inch, neck 4 inches. Iron perfectly uniform and fibrous, supported the weight 15 minutes, ...	21	1/8
6	Plate 11/16th inch thick, neck 5 inches. Iron good, 1/40th of the section crystalline, . .	19	1/36
7	Plate ½ inch, neck 5 inches. Iron fibrous except 1/50th of the section, ...	18	1/23
8	Plate ½ inch, neck 50 inches, ...	19·6	1/57
9	Plate ⅝ inch, neck 50 inches, ...	19·3	1/33
10	Plate ½ inch, neck 7 inches, ...	19·6	1/19
11	Plate ½ inch, neck 7 inches, ...	20·2	1/24
12	Plate ½ inch, neck 50 inches, ...	18·7	1/55

39. "From the mean of the above experiments the ultimate tensile strength of boiler-plate appears to be 19·6 tons; and it is worthy of remark that the ultimate strength is remarkably constant, although the iron comes from different makers from Staffordshire, Derbyshire, and Shropshire. The ultimate extension, on the contrary, is extremely irregular; indeed, some of the brittle, crystalline irons, selected as bad, which fractured suddenly without much increase of length, actually supported more weight than the more fibrous and ductile iron.

40. "In all these cases the iron was drawn in the direction of the fibre. In order to test whether the strength is influenced from this cause, two plates were selected, and from each plate two specimens were cut out, of similar form to those used in the experiments above. One specimen in each pair was cut out in the direction of the fibre, and the other across the fibre; in other respects they were precisely similar in form and dimensions. The following were the results :—

		Tons.		Tons.
"Ultimate strength when drawn in the direction of the fibre, . . .	Exper. 1,	19·66.	Exper. 2,	20·2.
Ultimate strength when broken across the fibre, ...	Exper. 1,	16·93.	Exper. 2,	16·7.

41. "The ultimate extension was also twice as great when the plate was broken in the direction of the fibre.

42. "The ultimate strength of wrought-iron, derived from experiments on 1-inch bars, has been usually taken at 25 tons per square inch. This conclusion is evidently erroneous as regards boiler-plate; indeed, this strength was not obtained from any iron used at the works.

43. "The best scrap rivet-iron, made by Messrs. Mare at their London works, the quality of the iron being unusually good, and the fracture beautifully fibrous, broke on an average with 24 tons per square inch, or 18·84 tons per circular inch. The length of the round rods experimented upon was 60 inches, the diameter $\frac{7}{8}$ths of an inch, and the mean ultimate extension (which was uniform) was $\frac{1}{8}$th of the length. The rods diminished very visibly in diameter before they were fractured, and drew into a conical neck at the point of failure."

44. Dr. Fairbairn's works also contain the results of his experiments on the "Influence of Temperature," ranging from zero to a dull red heat, on 16 pieces of Staffordshire boiler-plate and 14 pieces of scrap rivet-iron.

45. Mr. Clay, quoting experiments by the American Board of Ordnance, states that Russian iron broke with 62,644 lbs.; English rolled iron, 56,532; Lowmoor rolled, 56,103; American hammered, 53,913.

46. Mr. D. K. Clark, in his *Recent Practice* (1860),—a continuation of his truly excellent work on *Railway Machinery*, refers to five experi-

ments on Staffordshire plates by Mr. Brunel, which averaged 20·6; Staffordshire plates recently tested at Woolwich Dockyard, at 20 tons. "The best American boiler-plate for locomotives is stated by Mr. Zerah Colburn to have a tensile strength of 70,000 lbs., or above 31 tons per square inch of section; and that of the ordinary plate for locomotives is said to be 60,000 lbs., or 27 tons per square inch. . . . Upon the whole, English boiler-plates are of two classes—Yorkshire, and the manufacture of other districts, classed together as 'Staffordshire.' The ultimate tensile strength of boiler-plates for locomotives average as follows:—Best Yorkshire per square inch, 25 tons; best Staffordshire, 20; best American, 31; ordinary American, 27 tons. When we say 'best,' we mean best; that is to say, good in the superlative degree; not employing the phraseology of the manufacturers, who would call a superlatively good plate, 'best best best.'" Mr. Clark, referring to the publication of the first portion of the present series, says,—"The results, of which the following summary is an abstract, are both interesting and important; they represent the subject in a novel point of view, and form a record of the most recent attainments of the manufacturers of steel and iron in producing materials qualified to bear the strain and fatigue incidental to modern works of construction."

47. "Mr. S. Hughes, in an interesting paper "On Beams, Girders, &c.," published in *The Artizan*, February, 1858, remarks,—"There is probably no branch of experimental inquiry in which more varying and discordant results have been attained than in that which seeks to determine the absolute strength of wrought-iron subjected to a tensile strain, or to the action of a weight applied to tear it asunder.

48 "Writers on the strength of materials in the last century seldom assigned to bar iron a less tensile strength than 30 tons per square inch as the weight which would tear asunder a bar of ordinary wrought-iron 1 inch square. Thus, Emerson gives the tensile strength of bar iron at 34 tons; Telford, 29·29; Drewry, 27 tons; while at the present day Templeton gives 25 tons; Beardmore, 26·8; Brown, 25 tons; and Eaton Hodgkinson, probably from more careful experiments than any other, 23·817.

49. "The iron manufacture of this country has attained an enormous development, which, unfortunately, has not been accompanied by a corresponding increase of quality. On the contrary, all the earlier experimenters on iron found a greater strength than is now possessed even by the best qualities. It is foreign to the purpose of this article to trace the causes of this falling off and deterioration of a national manufacture; otherwise it would be very easy to show a case of serious national importance, which is perhaps more worthy of

the attention of our legislators than those to which their labours are commonly applied. Whatever be the causes—whether the spirit of speculation, the race of competition between the great iron manufacturers to produce their iron at the cheapest rate, or the introduction of new and cunning chemical secrets to enable them to work up inferior iron—certain it is that our manufacture of wrought-iron has been seriously deteriorating during the last half-century, and unless some improvement shortly takes place, we shall, before long, acquire a reputation for manufacturing only inferior iron."

50. These various extracts contain all the previous existing experiments the writer has met with in reference to this matter,* and he thinks that it cannot for a moment be denied that the subject, from its importance, was worthy of a more extended experimental inquiry than it had hitherto received. All must admit the truth of Mr. Hughes' remark regarding those varying and discordant results; but the writer does not think that there is any satisfactory evidence in the experiments adduced, to show that the iron now produced is inferior to that made during the last century. The difference, it is believed, was rather due to the experiments having been performed by so many, whilst the pieces tested by each were so few—to the different kinds of apparatus employed—to the results having been more carefully recorded by some than by others—to the extreme meagreness of the details, and to the complete want, with a few exceptions, of the makers' names or brands—which rendered futile any attempt at comparison. The various means employed of tearing the pieces asunder were—applying weights directly to the specimens,—single lever and weights,—compound lever and weights,—compound lever and weights combined with an hydraulic press,—hydraulic press alone, with either a loaded valve or a gauge to indicate the amount of pressure. In reference to the last machine, Dr. Rankine writes, "From experiments made by Messrs. More of Glasgow and by the author, it appears that in experiments on the tension and compression of bars, about *one-tenth* should be *deducted* from the pressure in the hydraulic press for the friction of the press plunger."

51. In all former experiments the ultimate strength or breaking weight per square inch of the specimen's original area alone is given, and the various pieces are rated accordingly, the one that stands highest being considered the best.

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* Since the first edition of this work was published, the writer's attention has been directed to the results of some interesting experiments by Robert Mallet, Esq., C.E., contained in the *Proceedings of the Institution of Civil Engineers for* 1859.

52. It seems most remarkable that an element of the highest importance should have been so long overlooked, namely, the *Contraction* of the specimen's area when subjected to considerable strain, and the still greater contraction, at the point of rupture, which takes place in a greater or lesser degree as the material is soft or hard, and the consequent influence this reduction must have on the amount of weight sustained by the specimen before breaking. The apparent mystery of a very inferior description of iron suspending, under a steady load, fully a third more than a very superior kind, vanishes at once when we find that the former had the benefit of retaining to the last its original area only slightly decreased; whilst the latter on breaking was reduced to very nearly a fourth of its original area—the one a hard and brittle iron, liable to snap suddenly under a jerk or blow, the other very soft and tough, impossible to break otherwise than by tearing slowly asunder. When engaged calculating and compiling the tables, this was considered not only an interesting circumstance, but one which required to be distinctly set forth in any statement made on the subject. Both the original and fractured areas are consequently stated in the tables, with the amount of reduction in the latter, and the per centage which that reduction bears to the whole of the original area. In the illustrative plates the original size is indicated by dotted lines, and the reduced size at fracture by full lines. A few examples will now be given by way of illustration, and in support of these remarks, *firstly*, from "Table B—Iron Bars," and *secondly*, from "Table D— Iron Plates."

IRON BARS.

		Index Number.	Original Area.	Fractured Area.	Difference between Original and Fractured Area.		Breaking Weight per Square Inch of	
							Original Area.	Fractured Area.
			Sq. In.	Sq. In.	Sq. In.	Per Cent.	Lbs.	Lbs.
a	Swedish R.F. (Charcoal),	270	·6650	·1963	·4687	70·5	47,534	160,520
b	Staffordshire Ⓛ do.	133	·7854	·3019	·4835	61·6	58,036	150,984
c	Yorkshire, "Lowmoor,"	105	·7854	·3632	·4222	53·7	65,166	140,920
d	Staffordshire B.B. Scrap,	138	·7854	·3739	·4115	52·4	59,570	125,130
e	Do. S. C. ♛ ...	148	·6220	·3318	·2902	46·6	61,263	114,846
f	Scotch Extra Best Best,	169	·8171	·4779	·3392	41·5	59,726	102,118
g	Do. Best Best,.........	185	·8012	·5441	·2571	32·1	66,363	97,721
h	Do. Common,.........	203	·8498	·6082	·2416	28·4	59,272	82,818
i	Do. Common,.........	201	·8498	·7238	·1260	14·8	60,722	71,293
j	* Russian, C.C.ND.,......	277	·7088	·6263	·0726	10·2	56,447	63,883

* NOTE.—This Iron, although possessing only a low degree of tenacity, from its extreme hardness and uncertainty, is very suitable for being converted into Steel, the purpose for which it is used.

IRON PLATES.

			Index Number.	Original Area.	Fractured Area.	Difference between Original and Fractured Area.		Breaking Weight per Square Inch of	
								Original Area.	Fractured Area.
				Sq. In.	Sq. In.	Sq. In.	Per Cent.	Lbs.	Lbs.
k	Yorkshire, ...	Lengthways	439	1·125	·714	·411	36·5	58,686	92,468
l	Do.		401	0·624	·477	·142	23·5	57,881	75,720
m	Staffordshire, S.C.		453	0·960	·754	·206	21·5	58,534	74,528
n	Do. Bradley,		471	0·995	·851	·154	15·7	60,697	70,968
o	Scotch Best Boiler,...		505	0·750	·655	·095	12·7	55,176	63,180
p	Staffordshire Best Best		479	1·015	·922	·093	9·1	48,853	53,781
q	Scotch Ship, ...		518	0·955	·911	·044	4·6	47,730	50,035
r	Do. Common, ...		542	0·748	·706	·042	5·6	43,831	46,439
s	Yorkshire, ...	Crossways	442	1·125	·897	·228	20·3	56,546	70,919
t	Do.		406	0·624	·522	·102	16·3	55,368	66,188
u	Staffordshire S.C....		456	0·960	·863	·097	10·1	55,414	61,643
v	Do. Bradley,		474	1·019	·937	·082	8·0	51,025	55,490
w	Scotch Best Boiler,....		512	0·750	·702	·048	6·4	48,000	51,291
x	Staffordshire Best Best		487	1·005	·950	·055	5·4	46,943	49,653
y	Scotch Ship, ...		525	1·064	1·037	·027	2·5	44,366	45,521
z	Do. Common, ...		546	0·748	0·737	·011	1·5	42,783	43,460

53. Although it is very important to ascertain and compare the breaking strains of various kinds of iron, it must at the same time be evident from these examples that that test alone does not afford the means of correctly estimating their respective merits, yet, strange to say, it has hitherto been so considered. One instance out of many may here be referred to, which occurred at the official inquiry by the Board of Trade into the melancholy loss of the "Royal Charter." Five of the plates recovered from the wreck were tested, and pronounced to be good solely because their mean breaking strain was 20·55 tons (46,032 lbs.) per square inch, instead of 19·56 tons (43,814 lbs.), Mr. Fairbairn's average for Staffordshire plates. As the writer had no means of judging, he expresses no opinion on that particular case, but he does not consider that statement any proof whatever that the quality was good, or suitable for the purposè, as the plates might, at the same time, be so extremely hard and brittle as not to bend and twist, but snap at once without a moment's warning.

54. When, however, we compare the breaking strain *jointly* with the contraction of the area at fracture, the case is vastly different, as we then have an opportunity of deciding correctly whether, on the one hand, a *high* breaking strain was owing to the iron being of superior quality, dense, fine, and moderately soft, or simply because it was very hard and unyielding; on the other hand, a *low* breaking strain might be due to looseness in the texture, or to extreme softness, although very close and fine in quality. On consulting the tables it will be found that in the hard and inferior varieties the amount of breaking strain varied considerably more than in the softer and superior kinds. The uncertainty of the former is strikingly exemplified in St. Rollox best rivet (No. 243, Table B), which bore 68,848 lbs., the highest strain, whilst another in the same lot broke with 47,248 lbs., nearly the lowest. This low strain was not due to contraction of area, for it only decreased 5·5 per cent.,—very different from another specimen (No. 257), Ulverston best rivet, which broke at nearly the same strain, viz., 48,870, but which contracted 55·5 per cent. In the summary of results, Tables G, J, and K, the various lots follow each other as nearly as may be in the order of their ascertained quality. On referring to Table G, the first on the list under "rolled bars" is Bradley's Ⓛ—breaking weight, 57,216 lbs.; and opposite this, in column c, is 27, which signifies that twenty-six of the other lots precede it as regards the amount sustained before breaking: it, however, contracted 60·9 per cent., whereas Govan ✱, or common (No. 130), bore almost the highest strain, viz., 63,956, but which only contracted 27·7, standing, in that respect, the thirtieth in the scale. The first on the list in Table J—Iron Plates, and also in Table K—Angle-iron, is Farnley, which, at the same time, resisted most and contracted most.

55. As it is important to distinguish between rolled iron and hammered iron, the succeeding remarks will be arranged under these heads respectively.

Rolled Iron.

56. For sake of comparison there are introduced into Table B the results of the testing of some pieces of puddled-iron rolled—or wrought-iron in its lowest grade—the breaking strain of which varied extremely from 55,323 to 20,521, contraction from 4·3 to 0·0.

57. In order to ascertain if the quality of the iron improved as the diameter of the bar became less, various sizes, within the limits of the testing apparatus, were taken, and we will now see the results from Table B. The difference was found to be greater in the inferior than in the superior makes; thus Govan ✱(lowest), 1⅛ inch, broke with 58,326 lbs., contracted 25·3, rose in the ¾ inch bars to 61,887—35·1; Govan ◈ (highest), 1¼ inch, 57,598—49·8, only rose in ⅝ inch bars to 58,199—50·1; Glasgow B. Best (medium), 1¼ inch, 54,579—35·8; ⅝ inch, 59,300—40·4; Dundyvan, 1¼ inch, 51,327—5·1; 1 inch, 53,352—8·5; Lowmoor, 1 inch, 61,798—53·1; 1/16 inch, 60,075—52·2. Of course these results were from different bars. It was considered, however, desirable to know the effects strictly due to additional rolling, and accordingly

four pieces were cut off *one bar,* and after reheating were reduced in the rolling-mill from 1½ to 1¼, 1, ¾, ½ inch, the breaking strains of which were 56,869, 57,379, 58,190, 59,708. The contraction of area varied only slightly, viz., 49·78, 49·19, 49·98, 49·29 per cent., see Table **N.**

58. The generally received opinion, that by removing the "skin" the relative strength was greatly reduced, or that a *rough* bar was much stronger than one *turned* to the same diameter, is proved to be erroneous by the following examples from Tables **B** and **G.** Dundyvan, rough, broke with 51,327, turned 55,995; Bagnall ♛ J.B., 55,000, turned 55,381; Glasgow B. Best, 54,579—55,533; Govan ◇, 57,598—57,288; Bowling, 62,404—61,477. In the last instance the rough bars bore rather more than the turned, but the difference is accounted for by the former being harder than the latter, as shown by the contraction of their respective areas, viz., 45·3 and 48·8; it will also be observed that they were from different, instead of from the same bars, as in the subsequent trials with the other brands. These experiments show further that the exterior portion is somewhat harder than the interior, as the turned pieces contracted more than the rough; they also draw out more in the direction of the length, as will be noticed under "elongation," and still further confirmation is afforded by the difference in appearance of the fractures.

59. Let us now see if reducing the bars by *forging* affects the comparative strength, &c. Dundyvan, 51,327, forged, 54,247; Glasgow B. Best, 54,579—56,112; Govan ◇, 57,598—57,095; Lowmoor, 61,798—66,392. The iron was generally rendered somewhat harder by the forging, as indicated by their areas contracting less than formerly; thus (in the same order) 5·1—10·8; 35·8—31·1; 49·8—49·2; 53·1—42·3. The difference in the last set was greater, owing to the bolts not having been re-heated after forging, as was the case in after trials, in order to remove any effects that might be due to "hammer hardening," as will be more particularly mentioned under "treatment," Section XIII.

60. We next proceed to compare the contents of these summary Tables as regards the breaking strain and contraction of area, respectively, of Bars, Angle-iron, and Plates; and in order to do so conveniently, they are presented in a more condensed form in the following Table. Still further to facilitate comparison, the contents are arranged in three separate groups, viz., 1*st.* The various qualities of iron manufactured in the same district. 2*d.* The qualities produced in different districts. 3*d.* The gross mean averages under the five qualities as branded. Of course, the "turned" and "forged" specimens are excluded from this Table.

	DISTRICT.	BRAND QUALITY.	BARS ROUND AND SQUARE.		
	DISTRICTS GROUPED.		No.	lbs.	℘ cent.
a	YORKSHIRE.	LOWMOOR, FARNLEY, BOWLING.	20	61,648	49·8
b	LANARKSHIRE.	◇ GOVAN ◇	12	58,181	49·4
c	Do.	Extra B. Best, Best Scrap.	30	57,411	39·9
d	Do.	Best Best, B. Best, B. Rivet.	61	58,737	36·0
e	Do.	Best, *	24	58,265	22·6
f	STAFFORDSHIRE	Charcoal Ⓛ	4	57,216	60·9
g	Do.	B. B. Scrap.	4	59,370	52·0
h	Do.	♛ S C, ♛ Best, Best Best.	21	58,698	39·5
i	Do.	♛, Best, K B M.	4	55,000	27·0
j	LANCASHIRE.	Best Rivet.	8	53,775	48·6
k	SHROPSHIRE.	♛ Best.	...	....	.....
l	DURHAM.	Best Best.	...	....	.....
m	DURHAM.		...	....	.....
n	SOUTH WALES.		...	....	.....
	BRANDS GROUPED.				
o	STAFFORDSHIRE	Charcoal Ⓛ	4	57,216	60·9
p	STAFFORDSHIRE	B. B. Scrap.	4	59,370	52·0
q	YORKSHIRE.	LOWMOOR, FARNLEY, BOWLING.	20	61,648	49·8
r	LANARKSHIRE.	◇ Govan ◇	12	58,181	49·4
s	LANCASHIRE.	Best Rivet.	8	53,775	48·6
t	LANARKSHIRE.	Extra B. Best, Best Scrap.	30	57,411	39·9
u	STAFFORDSHIRE	♛ S C ♛ Best, Best Best.	21	58,698	39·5
v	SHROPSHIRE.	♛ Best.	...	....	.....
w	DURHAM.	Best Best.	...	....	.....
x	LANARKSHIRE.	Best Best, Best Rivet.	61	58,737	36·0
y	STAFFORDSHIRE	♛, Best, K B M.	4	55,000	27·0
z	LANARKSHIRE.	Best, *	24	58,265	22·6
†	DURHAM.		...	....	.....
‡	SOUTH WALES.		...	....	.....
	SUMMARY.				
Total Mean Averages,		Charcoal Ⓛ	4	57,216	60·9
		LOWMOOR, B. B. Scrap, ◇ ◇.	44	58,244	50·0
		Extra B. Best.	30	57,411	39·9
		Best Best.	82	58,282	38·5
		Best.	28	56,633	24·8
			188		

ANGLE-IRON			PLATES					
BEAM AND STRAP.			LENGTHWAYS.			CROSSWAYS.		
No.	lbs.	⅌ cent.	No.	lbs.	⅌ cent.	No.	lbs.	⅌ cent.
4	61,260	41·4	21	54,980	20·9	24	50,540	12·8
...	....	.....	6	54,644	18·1	6	49,399	8·5
6	56,094	20·1	4	50,844	13·0	...	....	.....
24	54,930	16·8	38	49,077	8·2	34	43,359	4·4
3	45,439	9·2	18	46,438	6·9	18	41,527	3·7
...	....	.....	...	....	.....	...	....	.....
...	....	.....	...	....	.....	...	....	.....
12	54,558	18·2	30	52,168	12·9	29	48,840	7·8
9	51,227	17·7	8	45,686	9·4	8	44,748	6·6
...	....	.....	...	....	.....	...	....	.....
...	....	.....	5	52,362	15·0	5	43,036	5·3
6	53,548	18·3	37	51,308	12·9	38	46,381	7·4
4	50,807	11·7	...	....	.....	...	....	.....
4	41,386	9·8	...	....	.....	...	....	.....
...	....	.....	...	....	.....	...	....	.....
...	....	.....	...	....	.....	...	....	.....
4	61,260	41·4	21	54,980	20·9	24	50,540	12·8
...	....	.....	6	54,644	18·1	6	49,399	8·5
...	....	.....	...	....	.....	...	....	.....
6	56,094	20·1	4	50,844	13·0	...	....	.....
12	54,558	18·2	30	52,168	12·9	29	48,840	7·8
...	....	.....	5	52,362	15·0	5	43,036	5·3
6	53,548	18·3	37	51,308	12·9	38	46,381	7·4
24	54,930	16·8	38	49,077	8·2	34	43,359	4·4
9	51,227	17·7	8	45,686	9·4	8	44,748	6·6
3	45,439	9·2	18	46,438	6·9	18	41,527	3·7
4	50,807	11·7	...	....	.....	...	....	.....
4	41,386	9·8	...	....	.....	...	....	.....
...	....	.....	...	....	...	...	....	.....
4	61,260	41·4	27	54,812	19·5	30	49,970	10·7
6	56,094	20·1	4	50,844	13·0	...	....	.....
42	54,345	17·8	110	51,229	12·3	104	45,404	6·2
20	47,215	12·1	26	46,062	8·1	26	43,138	5·1
72			167			160		

61. A glance at this Table will show that the mean breaking strain in these *collected* lots varies in the Bar specimens from 61,648 to 53,775, difference 7,873, or 12·8 per cent. less. Angle-iron, 61,260 to 41,386, difference 19,874, or 32·4 per cent. Plates, lengthways, 54,980 to 45,686, difference 9,944, or 17·0 per cent.; crossways, 50,540 to 41,527, difference 9,013, or 17·2 per cent. The breaking strain of the plates was highest in those cut lengthways, or in the direction in which they were rolled, as was to be expected—the greatest difference, 9,326, or 21·7 per cent.; least difference, 0,938, or 2·1 per cent., the mean difference on the whole being 4,530, or 9·8 per cent. in favour of those cut lengthways. The amount of mean contraction varies in the Bar specimens from 60·9 to 22·6; Angle-iron 41·4 to 9·2; Plates, lengthways, 20·9 to 6·9; crossways, 12·8 to 3·7.

Hammered Iron.

62. The preceding remarks under this section refer to *rolled*, and we now turn our attention to *hammered* iron, firstly, in large forged masses, and secondly, in bars. Table B contains specimens cut out of two different crank-shafts of scrap-iron of the same size, for marine screw engines of 300 nominal horse-power, the exact position of the pieces being represented in the wood-cuts inserted in the Table. The difference in the breaking strain between the outside piece and that nearest the centre was in the one shaft 3,221 lbs., or 6·5 per cent.; in the other 1,141, or 2·6 per cent. Mean breaking strain and contraction of the six pieces cut out lengthways was 47,582—20·7 in the one, 43,759—23·1 in the other; cut crossways, 44,578—12·5 in the one, 38,487—8·5 in the other; difference in favour of those cut lengthways was in the two shafts respectively 3,004 and 5,272 lbs., or 6·7 and 13·7 per cent. The table also contains pieces cut crossways off one end of two armour-plates for H. M. "Black Prince," the mean breaking strains of which were 38,868 and 36,824, contraction 12·8 and 5·9 per cent. All these pieces were reduced to the required shape in the lathe, and not on the anvil, but some pieces were forged down, to ascertain the difference; these will be referred to in Section XIII.

63. Mr. Clay, of the Mersey Iron and Steel Works, the highest authority on the subject of forging large masses, states,—"Scrap-iron is that most generally used; but, far from agreeing with the generally received opinion that it is the best, we know that it is the very worst description of iron for the purpose; and, for more reasons than one— Let us first endeavour to see how this almost universal belief in the superiority of scrap-iron has arisen. At the time when small forgings

were first attempted to be made as an article of commerce, the manufacture of English iron was in such an imperfect state, and the quality so indifferent, that large quantities of the best iron had to be imported from Sweden and Russia, and for a long time the scrap-iron *was* of a quality that could not be approached by English iron of the period. Since that time the use of Russian and Swedish iron has been almost entirely discontinued, except for the manufacture of steel; the greater part of the scrap-iron now produced, therefore, is of a very different quality to that formerly known as best scrap-iron.

64. "In the ordinary manufacture of bar-iron, it is the practice in most works, in order to obtain it of the toughest and best description, to work and re-work it several times over. The number of workings that iron undergoes is marked by the number of 'best' stamps that it bears, as 'best,' 'best best,' 'treble best,' &c. But this progressive improvement has its limits, as will be perceived from a series of experiments which were instituted by the writer with the object of testing the correctness and limits of this improvement. Taking a quantity of ordinary fibrous puddle-iron, and reserving samples marked No. 1, we *piled* a portion 5 feet high, heated and rolled the remainder into two bars marked No. 2. Again reserving two samples from the centres of these bars, the remainder were piled as before, and so continued until a portion of the iron had undergone twelve workings. The following table shows the tensile strain which each number bore:—No. 1, puddled bar, 43,904 lbs.; No. 2, re-heated, 52,864; 3, 59,585; 4, 59,585; 5, 57,344; 6, 61,824; 7, 59,585; 8, 57,344; 9, 57,344; 10, 54,104; 11, 51,968; 12, 43,904. It will thus be seen that the quality of the iron regularly increased up to No. 6 (the slight difference of No. 5 may perhaps be attributed to the sample being slightly defective), and that from No. 6 the descent was in a similar ratio to the previous increase."

65. The results of some experiments on pieces cut out of the "monster gun," the dimensions of which were,—length, 15 feet 10 inches; diameter at base, 44, and at muzzle, 27 inches, are also given by Mr. Clay, and compared with the original iron of which it was formed: "The breaking strain in lbs. per square inch was,—original iron, 'commonly called common iron,' 48,384, 50,624; mean, 49,504. From muzzle of gun, with the grain, 48,384, 50,624, 52,864; mean, 50,462: across the grain, 41,644, 43,904, 50,624; mean, 43,390. Borings from gun worked over with coal, 60,584, 62,824; mean, 61,704. Boring from gun worked over with charcoal, 76,584. Swedish iron, as imported, ¾ square, 60,584.

66. "We have given these details to illustrate and enforce the pre-

ference given to puddled-iron over scrap-iron; but there is another very important reason why scrap-iron should not be used for the manufacture of forgings—scrap-iron is composed of many various qualities of iron, and all of them have their own special welding points. When worked together, one portion that is less refined is too much heated, and consequently deteriorated, before the more highly refined portions are at a welding heat, and we are thus placed in the awkward dilemma of either burning the one or of being unable to weld the other."

67. The writer begs respectfully to call attention to the important difference between the "scrap-iron" used at the forge in the formation of large masses, and that designated "best scrap" or "best best scrap" by the iron master, as he believes that the difference of opinion regarding scrap-iron is due in a great measure to the want of this distinction. The former is made up of old miscellaneous pieces, collected from every quarter, the latter composed of new iron, made in the same works, cut up and worked over again; consequently, the heterogeneous character of the one is totally unlike the homogeneousness of the other. It will be observed that Mr. Clay, in the preceding extracts, makes no mention of this distinction. Neither is the writer aware that any other person has done so. Table B contains specimens of both kinds, 288-295 and 783-796 cut out of crank-shafts of hammered "scrap-iron," whilst 137-140 were rolled "best best scrap." The mixed composition of the former is most beautifully illustrated by the singularly varied appearances presented by the fractures, more especially of specimens 793-796, as will be pointed out under that head in Section X.

68. As Mr. Clay, in his experiments on the effect of repeated workings, given above (64), found that the strength increased up to the fifth, and then correspondingly decreased, the writer regrets that the contraction of area at fracture had not also been ascertained and stated, as perhaps the decrease might have been owing to the iron becoming softer during the process.

69. Specimens 280-283 are bolts of old miscellaneous "scrap-iron," 284-287 are corresponding ones of "busheled iron," or new miscellaneous turnings; both sets were worked up under the hammer at the forge. Specimens 1117, 1118, Table N, are samples of Govan hammered bar-iron, which proved to be of extremely fine quality; 1119, 1120, were of the same square bars, but turned. These are additional proofs to those already mentioned (58), that removing the "skin" has no prejudicial effect.

70. Examples of some brands of Foreign flat tilted bars are given in

Table B, 264-278, and 803-810. These are shown to vary very considerably; in some instances the bad workmanship detracted from the fineness of the material.

IX. BREAKING WEIGHT AND CONTRACTION OF AREA—STEEL.

71. The following meagre and discordant statements as to the tensile strength of Steel, given in different works, prove that there was ample scope for further experiments to elicit some definite information, rendered all the more necessary on account of its recent introduction and extending application as a substitute for wrought-iron:—

72. Cast-steel, 142,122; 134,256; 130,000; 128,000; 88,657. Blister-steel, 133,152. Shear-steel, 124,400. Krupp's steel, 129,000; 117,707. Uchatius', 90,000. Mersey puddled-steel, 173,817; 160,832; 112,000; 94,752.

73. In paragraph 64 were given Mr. Clay's experiments to ascertain the effects of subjecting wrought-iron to repeated workings; he made a similar series on puddled-steel, and obtained, No. 1, puddled-steel bar, 96,911; No. 2, piled, 121,408; 3, 111,608; 4, 121,408; 5, 111,608; 6, 111,608; 7, 91,136; 8, 91,136; 9, 91,136; 10, 91,136. *Mem.*—"The weight increased 20 cwt. at a time." Regret was expressed (68) that the fractured area had not been also ascertained and stated, as perhaps the decrease in the strain sustained might be entirely due to the iron becoming softer. This conjecture appears to be confirmed, for Mr. Clay writes, in reference to the last,—"The appearance of the fracture of the sample bars, when broken by the hammer in the usual manner, presents to the eye a very slight difference, the colour and size of crystals being to all appearance much the same in No. 2 as in No. 10; but when torn asunder by a machine for the purpose, a very marked difference is observable, the higher numbers having a very fibrous silky fracture; and yet the characteristics of steel are perfectly preserved, for No. 10 hardens, takes the usual colours, in fact possesses all the distinguishing properties of steel." Further notice will be taken in Sections XI. and XIII.

74. In Section VIII. attention was called to the absolute necessity of stating the breaking weight jointly with contraction of area, as without the latter no correct opinion could be formed of the relative merits of different kinds of wrought-iron, or their suitability for different purposes. These remarks are certainly no less applicable to steel, as will be found by turning to Table A—Bars; thus Turton's

cast-steel for tools only contracted 4·7 per cent., with a strain of 132,909 lbs., whereas Homogeneous rivet-metal contracted 36·6 with 90,647; Mersey puddled-steel, 35·3 with 71,486; Blochairn puddled-steel, 19·0 with 65,255. Again in Table C—Plates, Moss & Gambles' cast-steel contracted 33·4 with 72,338 lbs.; Turton & Sons' cast-steel, 9·5 with 95,299; Mersey Co. puddled-steel, "hard" and "mild," respectively, 4·6 with 93,979, and 10·5 with 72,366.

75. The Summary Tables F and H contain the principal results of the other two, and are linearly represented in Plate VI.; but the specimens follow each other somewhat differently, beginning with the most highly converted and ending with the least; the former furthest, the latter least removed from that of wrought-iron. Of course it must not for a single moment be supposed that the writer considers one "the best" because placed first in these Tables; he has always considered that only the best which best answers its particular purpose. This remark would have been considered unnecessary but for the following statements.

76. The *Mining Journal*, 17th December, 1859, in noticing the publication of the former portion of these tables, remarked, though certainly quite inadvertently,—"From the tabulated statements referring to steel bars, it appears that the order of superiority runs thus,—Turton & Sons' cast-steel," &c. A letter appeared in the next issue, signed W. T.—"As your record of the experiments for testing the strength of cast-steel is calculated to convey a most erroneous impression as to the *value* of steel, permit me to state that it by no means follows that the steel which will bear the greatest tensile strain is the most valuable. Indeed, the choice of steel should always be made with due regard to the purpose to which it is to be applied. A first-rate steel for some purposes, and one which would stand more tensile strain than any other, provided that strain were gradually applied, might be altogether useless if employed for axles, or for any purpose where it would be subjected to vibration, as it would, under such circumstances, literally shake to pieces. I notice by your statement that you consider Bessemer's steel superior to Hoop L.; Howell's homogeneous metal better than Jowitt's spring steel; but I cannot say that I agree with you, although I do not dispute your correctness; for I consider the comparison much the same as stating that Irish linen is superior to flannel, or that pens are superior to paper, in which cases the difficulty of deciding the relative value would scarcely be more apparent to the general reader than the adoption of the tensile strength of metal as the sole standard for ascertaining the value of every description of iron and steel, no

matter for what purpose it was manufactured, is to the makers and consumers of ferruginous metals."

77. The same writer again stated, 7th January, 1861,—"It is almost impossible to say what steel is best unless we know what it is to be used for; but with such knowledge the consumer may avail himself of the tables to much advantage. Who would think of using Turton's tool steel, or Jowitt's spring steel, in the manufacture of, say, cranks for a steam-engine? They would find it rather a costly experiment. And, on the other hand, who would purchase Krupp's bolt steel, or Bessemer's tool steel, for making watch-springs? No one. Let consumers study the tables, and profit by them; but let them at the same time be careful how they draw their comparisons. . . . In fact, all that I could write would be but an enlargement of my statement, that the choice must depend entirely upon the intended application; and if the consumer does not know what properties the steel best suited to his purpose should possess, no tables can be compiled, or experiments recorded, which can assist him."

78. In the same issue appeared the following letter from the writer:—"It was only to-day that I read the letter of 'W. T.' in the *Journal* of Dec. 24. I beg to refer him and your readers to *The Artizan* of this month, which contains in full detail the tables and accompanying illustrations of the fractures. I can only be held responsible for the accuracy of these tables, &c., which I prepared, and not for any of the short notices of the experiments which may have appeared since their first publication in the *Transactions of the Institution of Engineers in Scotland.* I shall be glad to see 'W. T.'s' further remarks in the *Journal* after he has carefully examined the tables, &c.; having endeavoured to develop impartially the various peculiarities of the specimens tested, in order to ascertain their relative fitness for various purposes."

X. APPEARANCE OF FRACTURE—IRON.

79. Wrought-iron is considered to present two distinct kinds of fracture, which are variously designated, on the one hand, "fibrous," "tough," "red short;" and on the other, "crystalline," "granular," "cold short." Some say, "bright crystallized matter like steel;" others, "crystalline like cast-iron;" and others again, "granular like cast-iron." The "presence of sulphur" in the iron is stated by some to produce "red shortness," and phosphorus, "cold shortness;" another says, "From the forge and the rolling-mill we derive two distinct qualities of iron, known as 'red short' and 'cold short.'"

80. "The texture of commercial iron," remarks Mr. Tomlinson, "varies according to its mode of preparation. Pure iron, which has been drawn out under the hammer in all directions, has a finely granular structure, but when rolled into long bars, as usually sent into the market, the texture is fibrous in the direction of the length. The fibres may be made evident by the fracture of a bar under tension, or by acting upon it with dilute muriatic acid. Upon the perfection of this fibre much of the strength and value of iron depends; although by skilful management this silky character may be imparted to common varieties of the metal. The fibrous character is not, however, necessarily permanent, for after a time the metal has been found to assume a crystalline appearance, especially when subjected to constant vibrations, as in the tension rods of suspension bridges, the axles of locomotives, and of railway waggons," &c., and in a note refers to Mr. Hood's paper.

81. Mr. Tomlinson further says,—"Two common defects of bar-iron are known as *red short* and *cold short*. . . A very small amount of phosphorus will make bar-iron brittle, so small a proportion as 0·5 per cent. having been found to make it cold short. Sulphur has been assigned as the cause of the red short property of wrought-iron; the presence of only 0·0001 of sulphur renders the iron very difficult to work at a welding heat. A cold short iron is generally produced from a lean ore, in which case it has been found desirable to mix with it the rich red hepatic ore of Lancashire and Cumberland, which, if smelted alone, would produce red short iron. In this way two opposite defects are made to correct each other, and iron of average strength is produced."

82. Dr. Fairbairn observes,—"From the forge and the rolling-mill we derive two distinct qualities of iron, known as '*red short*' and '*cold short*.' The former is the most ductile, and is a tough, fibrous material, which exhibits considerable strength when cold; the latter is more brittle, and has a highly crystalline fracture, almost like cast-iron; but the fact is probably not generally known that the brittle works as well, and is as ductile under the hammer as the other, when at a high temperature. Mr. Charles Hood, in a paper read some time ago before the Institute of Civil Engineers, went into the subject of the change in the internal structure of iron independently of, and subsequently to, the processes of its manufacture. After adducing several instances of tough, fibrous malleable iron becoming crystalline and brittle during their employment, he attributes these changes to the influence of percussion, heat, and magnetism, but questions whether either will produce the effect *per se*. . . The crystallization of perfectly fibrous and ductile wrought-iron has long been a subject of dispute; and although we

agree with most of Mr. Hood's views, we are not altogether prepared to admit that the causes assigned are the only ones concerned in producing the change, or that more than one is *necessary*. On the occasion of the accident on the Versailles Railway, some years since, the whole array of science and practice were brought to bear upon the elucidation of the cause. Undoubtedly the broken axle presented a crystalline fracture, but it has never been ascertained how far heat and magnetism were in operation, as in the case of an axle, and more especially a crank axle, the constant vibration caused by irregularities in the way, and the weight of the engine, appear to be quite sufficient to occasion the breakage without aid from the other forces. . . . A French writer of eminence, Arago, appears to consider the crystallization of wrought-iron to be due to the joint action of time and vibration; but we think, with Mr. Hood, that time and its duration depends entirely upon the intensity of the disturbing forces, and, moreover, that the time of fracture is retarded or accelerated in a given ratio to the intensity with which these forces are applied."

83. In the "Institution of Civil Engineers" and in the "Institution of Mechanical Engineers" papers were read in connection with the fracture of railway axles, which led to most deeply interesting discussions for many meetings in succession, and in which persons of the highest eminence took an active part, and opinions the most conflicting were expressed by those apparently equally well qualified to judge. The following extracts are selected from *The Artizan's* report (vol. viii., 1850) of the proceedings of the last-named society on the subjects of papers on "Railway Axles and their Deterioration," by Mr. J. E. M'Connell, and on the "Form of Railway Axles," by Mr. T. Thorneycroft.

84. Mr. M'Connell stated, "The question of deterioration of axles, arising from the various causes which I have enumerated, is a very important one to all railway companies; that some change in the nature of the iron does take place is a well-established fact, and the investigation of this is most deserving of careful attention. . . . . Mr. M'Connell further remarked that he had one specimen of an axle which he thought furnished nearly incontestible evidence of the truth of his position, that a change took place in the texture of the iron. One portion of this axle was clearly fibrous iron, but the other end broke off as short as glass. The axle was taken and hammered under a steam hammer, then heated again and allowed to cool, after which they had to cut it nearly half through and to hammer it a long time before they could break it.

85. "The President (the late Robert Stephenson, Esq.) said, that Mr. M'Connell had expressed a strong opinion that a change took

place from a fibrous structure in iron to a crystalline one during the time of its being in use; and it would be satisfactory if an instance could be pointed out where this change had occurred, owing to vibration or any other treatment, for he had not been able to satisfy himself from many experiments that any such molecular change took place. Hammering a piece of hot iron till it is cold produced a hardness called crystalline; but the question for consideration was, supposing an iron axle were annealed by heating to a dull red heat and being allowed to cool slowly, would the 'texture' of that iron undergo any alteration afterwards from the vibration of the railway or any piece of machinery they were in the habit of employing? He had not been able to detect an instance of the kind; and in giving evidence before the Iron Girder Bridge Commission he mentioned cases of vibration going on from year to year without any sensible change occurring in wrought or cast-iron. For instance, they had the Cornish engine beam with a strain of 50 lbs. per inch, working eight or ten strokes per minute for more than twenty years; and certainly if a molecular change was introduced by vibration it ought to be by that continual concussion and vibration, but none was perceived. Again, the connecting rod of a locomotive was a piece of iron in a most perplexing situation, for one having more to do and having the strain changed more frequently it was difficult to conceive; and yet he had known the connecting rod of a locomotive engine to vibrate eight times in a second for several years' regular work, making more than 200 million times altogether, but the iron retained its fibrous structure; and he thought axles could not be subject to so much vibration. When, therefore, he found that a connecting rod did not change its molecular texture, he must say there were good grounds for doubting that iron changes its state in axles. . . . . He was only desirous to put the members on their guard against being satisfied with less than incontestible evidence as to a molecular change in iron, for the subject was one of serious importance, and the breaking of an axle had on one occasion rendered it questionable whether or not the engineer and superintendent would have had a verdict of man-slaughter returned against them. The investigation hence required the greatest caution; and in the present case there was not evidence to show that the axle was fibrous beforehand, but crystalline when it broke. He therefore wished the members of the Institution, connected as they were with the manufacture of iron, to pause before they arrived at the conclusion that iron is a substance liable to crystallize, or to a molecular change from vibration.

86. "Mr. Cowper did not believe that any axle which, when broken, proved to be crystalline had ever been fibrous in its character.

87. "Mr. Henry Smith observed that throwing cold water upon hot journals did great injury by crystallizing that portion of the axle.

88. "Mr. Slate did not think that any change from a fibrous to a crystalline texture was produced in iron unless it were strained beyond the limit of its elasticity. Some of the pump rods in Staffordshire, which had been in use for eighteen or twenty years, were subject to a strain of 3½ tons per square inch; and a short time ago he had occasion to ascertain their actual performance with reference to this very question, and this not being considered conclusive, he had made a machine in which he put an inch square bar, subjected to a constant strain of 5 tons, and an additional varying strain of 2½ tons, alternately raised and lowered by an eccentric eighty or ninety times per minute; and this motion was continued for so long a time that he considered it equal to the effect of ninety years' railway working, but no change whatever was perceptible; and, therefore, he was one of those who did not believe in a change from a fibrous to a crystalline structure in iron.

89. "Mr. M'Connell having been requested at the last meeting to furnish further proof of the change from the fibrous to the crystalline character produced in railway axles, and feeling convinced that a strict and careful examination of this important subject is a *necessity* in this age of railway practice, the inquiry has been resumed in the hope that the further information and experience gained may tend to a more perfect knowledge of the subject.

90. "Before stating the results of the different experiments which have been made with the view of ascertaining the cause and extent of the change from the fibrous to the crystalline appearance in railway axle iron, it must be observed that in this, as in some other matters of controversy, it is most difficult to produce full and conclusive proof that the iron which is produced of a crystalline character was once fibrous, as we cannot by any experiment show the change visibly taking place; but surely it is fair and reasonable to admit the *fact* of a change, when we find railway axles when new, from the particular mode of manufacture, present through every part of their substance a tough, strong, fibrous appearance; yet, after several years' use, we find axles of the same description, owing to the various deteriorating causes in action, break short at the back of the wheel, and then present an appearance totally different from the original structure of the iron as described above.

91. "Mr. Hodge said, so important was the question which presented itself with reference to changes in the structure of iron, that it had occupied the attention of the American Institute for two sessions, and

he thought that this Institution should not allow the subject to pass without a long and careful consideration, because it was necessary to have regard to the various circumstances under which the iron was manufactured, and the particular character of the iron itself.

92. "Mr. M'Connell considered that a change was produced from a fibrous to a crystalline structure by the effects of the concussion or jarring that the axles are subjected to whilst running on the railway; and it appears to be generally considered that such change takes place to a greater or less extent according to the circumstances, both in railway axles and in many other cases where iron is exposed to concussion or jarring, though there may be a difference of opinion as to the cause of the change. Another striking instance of the conversion of tough wrought-iron into a brittle material is shown in the chain slings used for carrying the bars during the process of hammering at a forge. The writer lately had an opportunity of observing a chain which had been in use for this purpose, and had become so extremely brittle that it was more like glass in its texture than the tough strong iron which it had been when first made; and he was satisfied that it had only been subjected to this extreme jarring action for a few months, and had not been otherwise employed. And further, it may be mentioned as a circumstance of common occurrence, that the porter-bars that are attached to the blooms whilst under the forge hammer became so brittle with the constant violent jarring to which they are subjected, that they break in two after a very moderate amount of work. In these instances there appears to have been no cause but the jarring or concussion to produce the change, as the iron was subjected to little strain in proportion to its strength; and the same may be observed of several of the instances mentioned before, in one of which the wrought-iron arms of a fly-wheel were jarred loose in the cast-iron rim, and broke off quite short, from the rapid and continued violent shocks caused by the cam striking the helve, although the iron was of the toughest description originally.

93. "The President observed that at the first discussion on this subject he took the liberty of drawing the attention of the members to the extreme care that was necessary in coming to any conclusion as to a molecular change in the constitution of wrought-iron. He thought that although there were a number of facts and statements on record which appeared to render it extremely probable that some change did take place in iron, yet that it only amounted to a change in the particles in their relation to each other, which might in the end produce a brittleness, or impart a crystalline character. These proofs were now multiplied in number, but he thought were not much

increased in pointedness, if he excepted the experiment with the chain, which was the most striking and marked instance of which he had yet heard. Hence they must conceive that a change takes place in iron if subject to vibration; but an investigation into the precise cause of the change would require more time and care than could at present be devoted to it. He might remark that since their last meeting he had turned his attention to ascertain, if possible, whether any real difference exists in the molecular arrangement of the material or structure of a piece of iron called crystalline, and a piece of iron called fibrous; and for this purpose he had examined them under a powerful microscope, and it would, probably, surprise the members to know that no real difference could be perceived, and that if he had not previously seen with the naked eye the specimens called fibrous and crystalline, he should not have been able to distinguish the one from the other in the microscope. The best specimen he could select of the kind called fibrous exhibited to the naked eye a laminal arrangement of dark and light lines, but the light lines composing the apparent fibre were, in point of fact, as crystalline as the other kind of iron, and, therefore, however fibrous it might appear, it was essentially a crystalline mass. Even in a piece of iron with large facets, which appeared extremely crystalline, when one of the crystals was examined it gave much the same appearance under the microscope as a fibrous surface gives to the naked eye; in fact, it would appear to consist of bundles of fibres broken through at certain angles, just as slate was observed in the quarries to break in particular rhomboidal forms Now, in the instance of slate, there was nothing fibrous or crystalline, but owing to the peculiar arrangement of the particles it exhibited on a large scale something resembling the appearances to be observed in Iron—like fibres being broken through in particular planes.

94. "It appeared to him that the fracture taking place in an axle at particular points might be illustrated by reference to a string being thrown into vibration. There were certain points of the string, called nodes, where no motion took place, because the action on the one side neutralizes the action on the other, and the particles at the nodes have double duty to perform, being pulled in opposite directions at the same time: hence what might be called the nodes in the axle had great action upon them, and this might induce a crystalline appearance, although it might not cause much change in the structure of the iron. It appeared to him a matter of extreme difficulty to conceive a change going on in the structure of iron, because it would involve a change from one kind of crystalline structure to another, which was next to an impossibility. He could imagine that a number of particles under

the influence of vibration might in time jostle each other into particular forms, and become fibrous; yet, when they examined most fibrous iron they would find it already crystalline, which involved the necessity of the molecules leaving one form of crystal and taking another. It would be well for the members to communicate to the Institution any well-authenticated facts of crystallization of iron, because nothing could have so important a bearing on the structure of railway axles as the means of tracing fractures to their real cause. Perhaps at their next meeting he might have the pleasure of exhibiting to the members certain microscopic results, but as yet he had not given the subject sufficient consideration to justify him in doing so.

95. "Mr. Adams thought that the appearance called crystalline was caused by nothing more or less than a bundle of fibres, consisting of many small crystals being sheared off square, forming one face.

96. "Mr. H. Smith inquired whether the Chairman thought there was any difference of strength produced. If they took the case of the common gag to the helve, or the prop that was placed under it, they found it became crystalline in the course of time, and very brittle, though quite fibrous at first. So also in the case of the chains on inclined planes, they broke very soon. He should like to know whether crystallized iron was not weaker than fibrous.

97. "Mr. M'Connell thought it was so. Whenever iron was subjected to a jar, the fracture was square across, and it seemed as if the whole structure of the iron became brittle like glass.

98. "Mr. T. Thorneycroft said, a mass of evidence might be adduced to prove that the internal structure of iron undergoes no change, unless there be a change of form; and that simple jarring or vibration will not destroy the fibre of iron, whereas bending, if long continued, will change the most fibrous iron into crystalline; therefore the author would fully subscribe to the opinion of one of the railway commissioners, who has stated, 'that it was of importance to avoid deflection on railway axles, as deflection was almost as fatal as fracture in causing accidents.

99. In *The Useful Metals and their Alloys* occurs the following passage under "Steel Manufacture:"—"The conversion of wrought-iron into a substance resembling cast-iron in many of its characters, by subjecting its particles for some time to a state of vibration, without any chemical change in its composition taking place, seems to indicate that the different properties of these three materials may depend on other circumstances besides the proportion the carbon bears to the iron."

100. In *The Engineer*, 26th December, 1856, in a letter on "Crystallization of Iron," Mr. Thomas Harrison, of the Trany Iron Works, writes,—"I see a letter from one of your correspondents, asking Mr. Forsyth, or any other of your readers, the reason why the fibre in iron of boilers becomes crystallized after a few years' use. The reason is obvious. We must first understand that all bodies are composed of atoms of a spherical form, held together by that force known as the attraction of cohesion. Then, in the manufacture of this body (iron)—it being in a semi-fluid state while subject to great mechanical pressure—the particles are brought within the sphere of this force, and assume the fibrous state, provided all the foreign matter has been driven off, such as sulphur, carbon, &c.; but if these bodies have not been driven off in the manufacture, then it is crystallized iron from the first. With this premise we cannot be at a loss to know the reason why the plate becomes crystallized after being in use a short time. Now, trace the process from the fibrous to the crystalline state. The subtle agent, caloric, penetrates into every interstice of the iron, deranging the molecular arrangement of the body, at the same time bringing it into a fit state for the absorption of the sulphur, carbon, &c.; which the iron greedily takes up, until it is dosed into the state called crystallized iron. If we take iron that has become crystallized by this means, and bring it to a semi-fluid state, and subject it to great pressure, it will again assume a fibrous state, because the sulphur, carbon, &c., that it has imbibed is again driven off."

101. In *The Mechanic's Magazine*, 3d May, 1861, under article "Expansion of Metals and Alloys," by Professor F. C. Calvert and others, the following occurs:—"In course of these experiments we have met with facts which we believe will prove highly interesting:

Iron Crystallized by Vibration.

90° to 10°—69, 1st. 66·5, 2d. 66·5, 3d. 65·5, 4th. 66·8 mean. Co-efficient of Expansion, 0·00119.

Mean of 100°, minus 20..............................68·5 mean. Co-efficient, crystallized by vibration, 0·00108.

We have been led to devote particular attention to these facts on account of the great use which is made of these metals in naval and other constructions."

102. *The Mechanic's Magazine*, 17th May, 1861, in a letter on "Crystallization of Iron," signed John Marshall, contains this paragraph:—"The theory that I maintain in regard to the crystallization of iron, in the case of railway axles and parts of machinery similarly circumstanced, is, that the rotation and friction of the axle in the axle-box,

accompanied by a moderate amount of heat, excites the latent magnetism of the molecules of the iron, whilst, at the same time, the vibration not only disintegrates and destroys the cohesion of the molecules composing the fibres, but assists in the excitation of the latent magnetism. As the molecules of the fibres become disintegrated, the molecules of greatest hardness, and consequently of greatest latent or visible magnetism, form nuclei, around which the softer molecules collect, forming crystals of various sizes, the hardest and most magnetic molecules forming the nuclei of the largest crystals; and further, as there is between the north and south pole of every magnet a neutral point, where there is no magnetic attraction, so the line of fracture would follow the neutral point between the crystals, varying from a straight line, or the line of direction of the breaking strain, to follow the weakest points of the magnetic cohesion of the crystals."

103. *The Journal of the Franklin Institute,* in some remarks on the structural condition of iron, contains the following statement:—"With regard to the important and much discussed question of the alteration of malleable iron when exposed to continuous vibration, concussion, or torsion, in consequence of which it requires a granular fracture, Fuchs admits that such an alteration takes place even in the best worked metal, but does not altogether agree with the explanation usually offered for it, viz., the gradual assumption of a crystalline texture; and is of opinion that it consists in the passage of the iron from a fibrous crystalline state to a granular crystalline state—a change in the aggregation, not an essential metamorphosis."

104. *The Engineer,* in several exceedingly interesting leaders, directs attention to the necessity of obtaining further facts bearing on this important and much controverted subject. The following extracts are selected from articles. On the "Manufacture of Locomotive Crank-axles," 10th June, 1859:—"Whether the question of the crystallization of wrought-iron under repeated concussions be ever settled, nothing is more common than to find, in the case of cranks which have broken after severe service, that the grain is in coarse crystals, often resembling zinc. In view of the possibility of the existence of this condition at the time the crank leaves the forge, it might be advisable to give it a low red heat, and leave it to cool slowly afterwards,—a process of annealing which has been found to be a complete corrective of the evils resulting from over-hammering common railway axles when nearly cold. . . There is some difference of opinion as to the relative strength of axles made respectively from new and scrap-iron. Bad work may be done

in either material, and with each the extremes of original quality are very wide. Good tough scrap-iron, carefully assorted so as to be as nearly as possible of uniform quality, will doubtless make an excellent forging, and, with care, even a sound, strong crank-axle."

105. On the "Effects of Percussion and Frost upon Iron," 18th June, 1861.—"Up to the present moment it has been very generally supposed, even by metallurgical authorities, that when wrought or malleable iron, even of a good fibrous quality, is acted upon by long-continued percussion, or by the tremulous motion to which it is subjected in railway work, it necessarily loses its fibrous nature, and acquires a crystalline character. During the present week this opinion has been strongly stated in an important article which the *Times* has quoted from *Aris's Birmingham Gazette.* The writer not only asserted this view himself, but also stated that any person of competent metallurgical knowledge can show that 'the crystallization of railway iron is no fault of the maker.' He further states that 'wrought, or malleable-iron (of which *all* railway tyres and axles are made) [?], when it leaves the maker's hands, is fibrous in structure, highly ductile, and might be actually tied into a knot.' This is too general a statement to be strictly true under any circumstances: it virtually implies, when taken with the writer's context, that wrought-iron is never manufactured for railway purposes in a wholly, or even a partially, crystallized condition. Good fibrous iron may be weakened both by percussion and by frost, and the action of these causes *may* change fibrous metal into crystalline; but to say that wrought-iron of a crystalline nature is never issued by manufacturers for railway purposes, is to contradict the experience of many engineers. The writer already quoted also urges the necessity of annealing railway iron—that is, exposing it to a red heat and allowing it to cool slowly—in order to restore its fibrous character, after crystallization has been induced by percussion or frost. He states that by this treatment 'the ductility of the metal will be restored, the crystalline structure removed, and the liability to sudden fracture in periods of low temperature greatly diminished.' He does not state in as many words that the strength of the iron, or that its tensile power of resistance, is restored; but this opinion is commonly held, and there is nothing in the writer's remarks expressing dissent from it.

106. "We need hardly say that this is one of the most important subjects that the engineers of the present day are called upon to investigate. The lives of many persons, and the property of many more, will be saved if the truth of the matter be discovered—lost, if it be not. For these reasons we cheerfully bring to the prominent

notice of our readers the new views concerning the action of percussion and cold upon wrought-iron, which were put forth in a report on the condition of the Niagara railway suspension bridge, by Mr. Roebling, a distinguished civil engineer of the United States. The views of this gentleman are as follows:—The force which holds together the molecules of iron is termed cohesion. Heat will expand iron, and when applied intensely and continuously will melt it, and will thus destroy all cohesion, and at the same time all elasticity, and all magnetic tension. It follows, then, that heat of a certain degree is opposed to cohesion and elasticity. And this explains why large masses of wrought-iron, when being forged, and thus subjected for a considerable length of time to an annealing process, will, in the centre, become greatly reduced in cohesion and elasticity. The previously existing fibre in the faggots will change into a coarse crystalline texture, because the iron being in a pasty and nearly molten state, and the mechanical effect of hammering being confined to the surface, and not penetrating to the centre, the formation of large crystals will be left undisturbed. Broken car axles sometimes appear to have undergone a similar change. The fact is that they generally exhibit a crystalline fracture. But Mr. Roebling suspects that many new axles, although manufactured out of fibrous rough bar, will, when finished and broken *before* they are used, also exhibit a crystalline fracture. In his own practice he has, he states, witnessed the fact that an experienced manufacturer, anxious to satisfy him, did not succeed in manufacturing round bolt of four to five inches in diameter out of good fibrous rough bar without producing a crystalline texture in the centre. The oftener he piled the iron the worse was the result. On the other hand, Mr. Roebling contends that he never heard of a failure when the bolt was forged entire under the hammer out of good, well-worked, and thoroughly hammered charcoal blooms with their rough ends cut off. Further, the most fibrous bar-iron may be broken so as to present a granular and somewhat crystalline fracture, and this without undergoing any molecular change in the texture. 'Take a fibrous bar, say ten feet long, but the longer the better: nip it in the centre all round with a cold chisel, then poise the bar upon the short edge of a large anvil and a short piece of iron placed eight or nine inches from the edge on the face of the anvil; then strike a few heavy blows upon the nip, so that each blow will cause the bar to rebound and to vibrate intensely, and the result will be a granular and somewhat crystalline fracture. Now take up the two halves, and nip them again all around, about one or two inches off the fractured ends, break them off by easy blows over the *round* edge of the anvil, and the fibre will appear again. This experiment proves that a break, caused by sudden jars and intense vibration, may show a granular and even crystalline fracture without having changed the molecular arrangement of the iron. All fibres are composed of mineral crystals, drawn out and elongated or flattened; and the fracture may be produced so as to exhibit in the same bar, and within the same inch of bar, either more fibre or more crystal. But a coarse crystalline bar will, under no circumstances, exhibit fibre; nor will a well worked-out fibre exhibit coarse crystals.' Mr. Roebling's view of the matter is, that a molecular change, or so-called *granulation* or *crystallization*, in consequence of vibration or tension, or both combined, has in no instance been satisfactorily proved or demonstrated by experiments.

107. "He further insists that crystallization in iron or any other metal can never take place in a cold state. To form crystals at all the metal must be in a highly heated, or nearly a molten state. On the other hand, he is witnessing the fact daily, he says, that vibration and tension combined will greatly affect the strength of iron *without* changing its fibrous texture. The cohesion and elasticity of wire and wire rope will be rapidly destroyed by great tension and vibration combined. Whether we are able to account for it or not, '*there stands*,' says he, '*the fact*.' But what is true of iron wire applies with equal force, and, when all circumstances and conditions are duly proportioned, with even greater force, to large masses. The extensive opportunities which his pursuits offer to make experiments and observations on wire and wire rope, authorize, he believes, a positive expression on this subject.

108. "Mr. Roebling goes even further. The opinion prevails, that a well drawn-out fibre is the only sure sign of tensile strength. This, however, is true, he affirms, only when applied to *ordinary* qualities of bar or rail iron. The fact is different with good charcoal iron, and with steel. The greatest cohesion is accompanied by a fine, close-grained, uniform appearance of texture, which, under a magnifying glass, exhibits fibre. The colour is a silvery lustre, free from dark specks. The finer and more close-grained the texture, the nearer the iron approaches to steel. Those who are familiar with good Swedish or Norway iron will support these statements. These facts alone should be sufficient to disprove the erroneous notion that good iron and steel, which should always be granular, will become so only by vibration, and will thereby lose their strength. But it is important to keep in mind the distinction between a fine uniform granular fracture and a coarse crystalline fracture. Where coarse crystalli-

zation appears there is a want of contact and compactness, and, consequently, of cohesion and strength generally."

109. On the "Duration of Iron Structures," 25th January, 1861. —"Mr. Roebling suggests a theory by which he accounts for the weakening effect which vibration under tension and bending produce upon iron. It is as follows:—All irons form alloys of pure iron mixed with carbon and other impurities. A certain amount of impurities, in the shape of good cinder, appears to be necessary to impart strength and cohesion to this metal, and also to make it malleable, and to give it welding properties. The purer the iron is, the higher the heat at which it will weld. Compare, for instance, good Swedish iron with common puddled bar: while the latter will weld at a low heat, the former requires a much higher heat. Compare their fracture and colour: the good Swedish bar will exhibit either a fine granular appearance or fibre, accompanied by a silvery lustre, showing comparative purity; the puddled bar will be of a dark colour, with a graphite lustre, and will show a coarse texture, or loose fibre. During the process of puddling, as well as of blooming, the melted pig-iron is mixed with cinder; and this mixture, which will adhere by cohesion, prevents the formation of large crystals, which is the tendency of pure iron in a molten state. Now, by working (bringing to *nature*, as the puddler calls it), this mixing and crystallization is promoted. The subsequent squeezing and rolling of the puddled ball, or the hammering and shingling of the bloom, will have the effect of condensing, laminating, reducing, and drawing out these crystals, at the same time removing and squeezing out the superabundant cinder from between the metallic crystals. Thus, the drawn-out fibre is composed of an aggregate of pure iron threads and leaves, enveloped in cinder. Pure iron, as well as very impure iron, is weak; the maximum strength and toughness is obtained by a certain mixture of pure iron with carbon and cinder, thoroughly worked and incorporated. When the fibrous and laminar aggregation becomes so dense as to be fit for the manufacture of steel, then are, by this very process, sufficient impurities expelled, and the greatest degree of cohesion is obtained. Hence, strong steel can only be made of strong iron, no matter what chemicals may be administered during the process. 'Keeping the above process before our minds, we may now understand,' says Mr. Roebling, 'why even the best fibrous wrought-iron, when exposed to long-continued vibration under tension, or to torsion, bending, or twisting, must inevitably become brittle, *because the iron threads and laminæ become loosened in their cinder envelopes.* But the cohesion between the iron and its

cinder once destroyed, and its strength is gone. Now, whether cohesion is the result of magnetic attraction (according to Faraday) or otherwise, this process appears to be purely mechanical.'" But let the explanation which is here offered be correct or not, says Mr. Roebling, the fact remains, that fibrous iron, and all kinds of iron and steel, will be rendered brittle by vibration and tension, or by bending and twisting, *without* undergoing any mysterious change in its molecular arrangement. We think it will be admitted that the author's theory is, to say the least, well deserving future consideration."

110. The previous extracts generally refer to supposed changes in the iron, independent of and subsequent to its manufacture; a few others will now be given on crystallization occurring in the production of large forged masses, and no higher authority can be quoted than Mr. Clay, of the Mersey Forge, who observes,—"A great deal has been said and written with reference to a supposed deterioration, or as it has been called, 'crystallization' of iron when worked into large masses, from long-continued and frequent heatings; it has also been asserted that the iron, while lying in the furnace, is continually attracting carbon from the grate, until, in course of time, it becomes carburetted, that is, re-converted into pig-iron. When this theory was first propounded the writer determined to test its accuracy, and that in the presence of the gentlemen by whom it had been promulgated. A small knob, or corner, was accordingly detached from a large forging which had been overheated, or burnt; it broke off with a large flaky appearance, very similar to some descriptions of lead ore. This was pronounced to be very similar in its nature to cast-iron, and in the so-called crystallized state. Proceeding to the smith's department, the iron was heated in the fire, and drawn down to about three times its original length. It worked well under the hammer, and when broken again in the usual way, was as beautifully fibrous as the iron from which it was originally made. This experiment led to the conclusion that the iron acted upon was very different in its nature from cast-iron, and certainly failed in sustaining the crystallization theory. . . . .

111. "It seems to us that all wrought-iron is, more or less, crystalline in its structure; and that the difference between what we call fibrous and crystallized iron only consists in the degree of fineness in the crystals, and perhaps in the manner in which they are laid together; the presence also of foreign matter, such as silicon, in some form, may also have its influence. Whatever the cause may be, however, it is known that a piece of good fibrous iron will break under the smith's hammer with a long silky appearance; if suddenly fractured by an

irresistible blow, the same piece of iron will break crystalline, but the crystals will be very fine and close, and of a good colour. In some experiments made at Woolwich in 1842, to test the effects of shot against wrought-iron plates, and determine whether wrought-iron was a suitable material for ships of war, it was found that the strongest and most fibrous plate-iron, when struck by shot, was instantaneously crystallized, while the pieces struck out were so hot that the fragments, even after passing a considerable distance through the air, could not be handled with the naked hand; in many cases the fracture had that blue appearance which is indicative of considerable heat.

112. "A 68-pounder wrought-iron gun burst with the first charge, at Woolwich, on the 12th July, 1855: on examination, the iron was pronounced to be crystallized, and its nature changed, by long exposure to great heat. This crystalline appearance was, most probably, the result of the very sudden disruption, as in the experiment with the iron plates; and according to our view of the case, is traceable to bad workmanship. A considerable portion of the bars of which the forging was composed had never been welded at all, and no doubt the fracture commenced with these false weldings. The crystalline appearance, where the iron was torn from the solid mass, arose, at any rate to a great extent, from the sudden fracture. Other causes, no doubt, assisted, among which the selection of iron too highly refined may be included. From this crystalline appearance the authorities of the Ordnance Department arrived at the conclusion that large masses of iron, from long-continued heating, have a tendency to crystallize, and lose the properties peculiar to wrought-iron. . . . . .

113. "Having thus endeavoured to explain the meaning of the term 'crystallization,' let us now endeavour to find the causes which produce this result. The change in the structure of the mass of iron, when it occurs during the process of heating, is usually produced from the furnace being urged to a much greater heat than is necessary for welding the iron; in fact, the outside first, and, if the heat be not checked, the whole of the mass, is reduced to a pasty or partially fluid condition. The structure of the iron is thus entirely changed, and in the process of cooling the mass, crystallization takes place in the same manner as with other substances which crystallize in passing from the fluid to the solid state. Under these circumstances, the iron may be injured—in other words, it may be burned; but we are not to suppose that such a result is either inevitable or by any means common; on the contrary, the heat necessary to produce the evil is with difficulty obtained in an ordinary furnace, under the most favourable circumstances."

114. The above extracts have been given with the view of showing that this part of our subject was not only interesting and important, but offered a fair field for further inquiry; and it is hoped that the extensive series of fractured specimens, carefully preserved for reference, together with the ascertained facts, will place this vexed question in a more satisfactory position than it has hitherto occupied.

115. The diversified *appearances* presented in the present series of fractures have been classified as follows:—

STEEL,	Granular. Granular and crystalline. Crystalline and fibrous. Granular and fibrous. Fibrous.	WROUGHT-IRON,	Fibrous. Fibrous and crystalline. Crystalline.

116. Under each of these classes there are many gradations as regards the fineness or coarseness of the texture. It only confuses matters, however, to liken the crystalline appearance of wrought-iron either to cast-iron or to steel, as each has perfectly distinct characteristics of its own, although in some cases they approach much nearer each other than in others.

117. Full-size delineations of the Iron fractured specimens, selected as representatives of the various classes, are given in Plates II., IV., V., XV., XVI. In Plate II. the softest of the bar specimens is shown at K, the hardest and least ductile at Z. Plate IV., specimen M, is the most ductile of the fine fibrous class; specimen Q, of the finely crystalline and fibrous; specimen T, of the coarsely crystalline and least ductile variety; specimens U, V, and W, of the coarser kinds of fibrous laminated plates; and X, unlaminated. Plate V. contains miscellaneous specimens, viz., puddled-iron, a, b; the singularly varied appearances of pieces cut out of crank-shaft, which were *turned* down, c, d, e, g, h, and *forged* down i; various kinds of iron bars partly converted into steel, k, l, m, n, o; iron bar after being "cold-rolled," p; from the same piece annealed, q; hammered bar-iron, r; different qualities of angle-iron, s, t, u, v, w; coarsest description of strap-iron, x. Plate XV. illustrates effects sometimes produced in the appearance by altering the shape of specimens; figs. A, C, E, &c., are fractures at parallel portion, and figs. B, D, F, &c., corresponding ones at grooved portion. In Plate XVI. fractures of the screwed bolts are exhibited; those wholly fibrous, A, B, C, H, fibrous and crystalline, G; wholly crystalline, D, E, F. The following are specimens of those acted upon by acid to develop the texture;—fig. 1, highly worked rolled bar; fig. 2, slightly worked rolled bar; fig. 3, puddled-iron

rolled; fig. 5, piece cut out of crank-shaft, lengthways; fig. 4, piece cut out of armour-plate, crossways.

118. These illustrative plates were prepared with extreme care, in order to convey a correct general idea of the various peculiarities in the specimens; but the actual fractures must themselves be examined to observe many minute distinctions as regards lustre and gradations in the colour, alike impossible to represent or describe.

119. The conclusions come to by the writer in course of the present experimental inquiry will now be stated, after which the evidence in support of them will be produced. 1. Whenever wrought-iron breaks *suddenly*, a *crystalline* appearance is the invariable result; when *gradually*, invariably a *fibrous* appearance. 2. Whether, on the one hand, it is finely or coarsely crystalline, or, on the other, the fibre be fine and close, or coarse and open, depends upon the quality of the iron. 3. When there is a combination in the same bar or plate of two kinds—the one harder or less ductile than the other—the appearance will be partly crystalline and partly fibrous, the latter produced by the gradual drawing-asunder action previous to and at the time of rupture; whilst in the former the iron breaks suddenly, without elongating at time of rupture. 4. When the proportion of the harder is considerably less than the softer, the former snaps suddenly, whilst the latter continues stretching; but when nearly equal, or the less ductile predominates, both portions break together, or almost at the same moment,—the one part, gradually arriving at its limit of endurance, breaks with a fibrous appearance, whilst a greatly increased strain consequently coming on the remaining portion, it suddenly gives way, producing a crystalline appearance. 5. The relative qualities of various irons may be pretty accurately judged of by comparing their fractures, provided they have all been treated in precisely the same way, and all broken under the same sort of strains similarly applied. 6. By varying either the shape, the treatment, the kind of strain, or its application, pieces cut off the same bar will be made to present vastly different appearances in some kinds of iron, whilst in others little or no difference will result.

120. Numerous instances of fractures wholly fibrous, some wholly crystalline, and others partly both, are severally contained in Table B—Bars, Table D—Plates, and Table E—Angle-iron. Under the heading "fracture" will be found the classified appearance of each specimen throughout the entire series; and as already mentioned, "0" signifies that it is wholly fibrous, and "100" wholly crystalline. A very fine example of the union in one bar of five distinct layers, two fibrous and three crystalline, occurs in Bradley's

S C Crown, No. 147, Table B, and in the corresponding specimen, 1507, Table T, both of which pieces stretched a certain amount, and then suddenly gave way.

121. A few examples will now be given, to prove that the appearance of the same bar may be completely changed from wholly fibrous to wholly crystalline, without calling in the assistance of any of those agents already referred to—viz, vibration, percussion, heat, magnetism, &c.;—and that may be done in three different ways:—1*st*, by altering the shape of the specimen so as to render it more liable to snap; 2*nd*, by treatment making it harder; and 3*rd*, by applying the strain so suddenly as to render it more liable to snap from having less time to stretch.

122. *Firstly*,—By altering the shape, rendering it less liable to draw out, which was accomplished by simply reducing the diameter by means of a narrow square-edged tool; and as it was considered desirable not only to ascertain that such a difference could be produced, but to give ocular demonstration by presenting in the same piece two fractures so widely different in their appearance as fibrous and crystalline, the following method was devised:—Instead of forming heads or shoulders on the bolts, as previously done, the two ends were screwed, the one to double the length of the other, and in the centre of the long screw a narrow square-edged strip was cut out, as shown in Plate XV.; the bolt was then inserted into the shackles (fig. 6, Plate I.) and broken; it was afterwards again placed in the lathe, and the space between the screws reduced to the same size as the grooved portion, when it was again broken. We will now see the varied results. Compare two bars of the same quality, viz., Bowling (1207) and Lowmoor (1204). The former stretched at the grooved portion before breaking, whereas the latter snapped: the one was wholly fibrous, as shown at B, the other almost wholly crystalline, as at M. These two bolts, when broken at the reduced portion, represented alike the same very fine fibrous fractures as at A and L respectively. The question may be asked, Why should the one grooved specimen stretch, and not the other? In reply, attention is called to the fact, that the one bar is much softer than the other, as proved by the area of the one, 1209, Table P, contracting 56·44 per cent., with a breaking load of 58,678 lbs., whilst 1206 only contracted 51·00, with a load of 65,166 lbs., and hence, it is submitted, arose the diversified results presented. Next compare two bars of Glasgow B. Best, 1222, which, at the grooved part, had 4 per cent. of the area crystalline, as at H; and 1231, which had 96 per cent. as at S. In this instance the central portions broke differently—the one wholly

fibrous, as at G, the other 88 per cent. crystalline, as at R; but the cause is again evident from the one being a much harder iron than the other, and consequently more liable to snap. Govan hammered bar, 1201, broke 78 per cent. of the area crystalline at the grooved portion, but on repeating the experiment, it broke wholly fibrous, as at K, as it suddenly drew out on applying the last weight to the steelyard. Had this bar been slightly harder it would have broke alike crystalline on both trials, and if, on the other hand, softer, both would have been fibrous. Table P and Plate XV. contain other examples. In order to remove any suspicion that might arise as to the action of screwing having anything to do with the altered appearance of the fractures, Lowmoor bar, 1243, was grooved in the middle space away from the screwed ends, and when broken showed 90 per cent. crystalline.

123. *Secondly*,—We will now proceed to adduce instances in which screwing the bolt, by exerting a hardening influence on the surface of the iron, and thus preventing it from stretching, caused it to break suddenly; and other instances will be brought forward where no such hardening had taken place, and consequently the screwed bars presented the same fibrous appearance as they did previously in the unscrewed bars. In the one series of bolts the screw dies employed were very blunt from long use, and accordingly the formation of the thread was partly due to a cutting and partly to a squeezing action; whereas in the other series, the dies, being new, cut out the thread sharply with comparatively little compression. "Lowmoor" unscrewed bars, 105 to 108, Table B, all present very fine fibrous fractures, whilst the bolts from the same bars which were screwed with the old dies, 1365 to 1370, Table Q, are all wholly crystalline, extremely fine; but those screwed with the new dies, 1373 to 1380, yielded fractures nearly wholly fibrous. Compare "Glasgow B. Best" unscrewed bars, 213 to 216, Table B, which are nearly wholly fibrous; whilst the bolts screwed with the old dies, viz., 1406 to 1420, Table Q, are generally nearly wholly crystalline, but not so fine as the Yorkshire quality; those screwed with the new dies, viz., 1421 to 1426, are partly fibrous and partly crystalline. Rupture took place at the screwed part, in the one series suddenly, in the other more or less gradually, from the screwed part stretching. In a series of bolts which were partly converted into steel in a case-hardening furnace, the previous fibrous appearance of the bars was changed into crystalline, and it is submitted the change was produced thus:—the interior portion remained iron, while the exterior was converted into steel much harder and less ductile than the other; the latter only stretched

slightly, and on snapping, its share of the strain being suddenly added to that already borne by the soft portion, caused instant rupture. In proof of this, a few examples, 1051 to 1054 and 1061 to 1068, all broke with the central portion composed of brilliant crystals, varying much in size, with a clearly defined ring of fine granular steel outside, as represented at **k**, **l**, **m**, Plate V.; but in 1055, 1057, 1059, and 1060, a portion of the interior broke fibrous, these bolts having continued to elongate after the steeled portion had given way, as shown at **o**. We will now see the effect peculiar treatment has on changing the appearance of iron plates. Six pieces were cut from a plate of "Blochairn Best," three lengthways and three crossways, and two of each were "cold rolled" by Mr. Lauth. 1137 and 1140 Table **O**, ordinary state, broke gradually, wholly fibrous; 1135 and 1138, "cold rolled," extremely hard, broke suddenly,—1135, 54 per cent., and 1138, 80 per cent. crystalline; 1136 and 1139, "cold rolled" and then annealed, were again soft, broke gradually, and wholly fibrous. A bar of the same kind of iron was similarly treated and tested; the "cold rolled" pieces, in this instance, were not so hard, and stretching a little before rupture, yielded a fibrous result. See Table **N**, 1081 to 1090.

124. *Thirdly*,—Let us see the effect produced on bolts in every respect the same as formerly, and broken under the same kind of strain, namely, tension; but instead of adding the weight slowly until ruptured, a certain per centage of the ascertained breaking weight was applied at once. (This operation will be described in Section XVII.) Compare four bars of "Glasgow B. Best:" 1530, Table **T**, broke instantaneously with a load of 93·8 per cent., fracture wholly crystalline instead of only 5 per cent. crystalline, as 213, Table **B**, off the same bar; 1531, broke suddenly with a load of 94·5 per cent., fracture 72 per cent., instead of 1 per cent. crystalline, as in 216; 1543, broke with a load of 97·8, fracture 22, instead of 2 per cent. crystalline, as in 1094, Table **N**; 1536, broke very gradually, with a load of 91·2 per cent., fracture wholly fibrous, same as 1091. It is interesting to observe that the variations of the fractures, under *suddenly* applied strains, fully corroborate the accuracy of the previous experiments under *gradually* applied strains. Thus these four bars were found to vary very considerably as regards softness. The first, with a breaking strain of 60,817 lbs., only contracted 32·7 per cent.; the second, with 58,351 lbs., 41·4; the third, with 56,604 lbs., 42·4; and the fourth, with 55,717 lbs., 44·2 per cent. Bagnall ♛ J B, 1545, with a load of 88·1 per cent., broke very suddenly after stretching, fracture wholly crystalline, instead of 46 per cent., as in 703, Table **B**, off the same bar. Bradley ♛ S C, 1507,

with a load of 79·2 per cent., broke quickly, fracture 60 per cent. crystalline, exactly corresponding with 147. Lowmoor, 1510, broke gradually, with a load of 94·4 per cent., fracture wholly fibrous, like 106. Bradley Ⓛ charcoal iron, 1501, had a load of 108·6 per cent. applied, with the view of breaking it instantaneously, if possible; but it drew out most beautifully, emitting at the same time a considerable degree of heat, and producing a very fine soft fibre, with, as in specimens 133 to 136, a somewhat peculiar fracture.

125. It will be observed, as was indeed to be expected, that the more iron is worked and rolled the more ductile it becomes, and has consequently the less tendency to break suddenly with a crystalline fracture. A few examples may be given from Table B. The fractures of 12 pieces puddled-iron rolled, or wrought-iron in its lowest grade, yielded a mean of 78 per cent. coarsely crystalline; the remaining portion, in these pieces, was not fibrous, but consisted of dark-coloured flaws; Dundyvan, common (8 pieces), 95 per cent. crystalline; Govan ✱ (12 pieces), 32; Govan B. Best (16 pieces), 22; Govan Extra B. Best (24 pieces); and Govan ◇ (12 pieces), were wholly fibrous, the latter very fine, close, and uniform in texture.

126. It has already been mentioned (58) that the outer portion or skin was somewhat harder than the inner; we will now find this further proved by comparing the fractures of the *unturned* specimens with those *turned*. Dundyvan, 1¼ inch diameter, 98 per cent. of the area crystalline, whilst pieces of the same bars turned to 1 inch showed only 70 per cent.; Bagnall ♛ J B, 1¼ inch, showed 15, and turned to 1 inch, 11 per cent.; Glasgow B. Best, 1¼ inch, showed 5, and turned to 1 inch, 8 per cent.; in this case the crystalline portion was in the centre of the bars, and consequently unaffected by the turning.

127. The foregoing remarks and conclusions refer to experiments on rolled bar, plate, and angle-iron, and also on hammered bar-iron. A few observations will now be made on the fractures of those specimens cut out of the large forged crank-shafts, viz., 288-295, and 783-796, Table B; 1096-1102, Table N; and 1546-1550, Table T. In some the appearance only varied slightly, in others considerably, and in a peculiarly marked manner in others. Both of these shafts were formed of "scrap slabs laid on in no regular way," writes the maker; "and of course, being iron collected from so many places, would most likely be of many kinds,"—which was found to be the case, as shown in the singularly varied appearances, especially of 793 to 796.

Specimen 796 is a good illustration of the truth of Mr. Clay's remarks (66) against using in the same forging iron of various qualities, requiring different degrees of heat, as one-half of that specimen is brilliantly crystalline, the other discoloured and burned. Specimen 794, fig. **d**, Plate V., is a most beautiful example of three combinations in one piece, viz., very large crystals, a seam or weld, and small crystals, the last of the same class as met with in the other specimens, the first only found, and that in a less marked degree, in 793. These very large crystals seem to be those described by Mr. Clay (113) as being sometimes formed during the production of large forged masses. Specimen 795, fig. **e**, is wholly fibrous, of the same kind as partially found in some of the other shaft specimens, but distinctly different from that in the rolled bars, &c. All these pieces were cut out and turned down, and truly represent the iron as it existed in the shafts.

128. We now turn to Table N, also containing pieces, but subjected to various kinds of treatment to observe the effects: 1096-1098 were forged round from blocks 1$\frac{3}{4}$ inch square, and reduced in the lathe from 1$\frac{1}{8}$ to 1 inch: the result was greatly to increase their strength, and, as will be noticed in Section XIII., the fractures much more closely resembled those of rolled iron. One of these specimens, 1096, is represented at **i**, Plate V. Specimen 1100, from one shaft, and 1101, from the other, were cut out and turned down, then highly heated and suddenly cooled in water;—observe the difference: 1100 wholly crystalline, generally large, as at **g**; 1101 nearly wholly fibrous, as at **h**; the former broke very suddenly with a low strain, the latter gradually with a high strain. The writer intended to have tried some additional experiments, but, unfortunately, the remaining pieces which he had set aside were accidentally taken away and used.

129. Specimens 797-802, Table B, cut crossways off the end of two forged armour-plates, yielded fractures nearly wholly fibrous, of a laminated formation, as at **f**, and closely resembling some kinds of rolled plates.

130. Reference will now be made to some of the statements and opinions entertained by others, as given in the extracts previously quoted. Although "it was found that the strongest and most fibrous plate-iron when struck by shot" presented a crystalline appearance, it does not necessarily follow that it "was instantaneously crystallized," as stated (111) by Mr. Clay. The difference, according to the writer, was merely in appearance, not in reality, and was consequent on the plate being fractured so suddenly that no time was allowed for

stretching, and hence it was impossible that the fracture could be anything else but crystalline.

131. Because "railway axles," "chains," "chain-slings," "porter-bars," "arms of a fly-wheel," &c., broke, and the fractures showed a crystalline instead of a fibrous appearance, many eminent persons came to the conclusion that the iron had actually undergone a mysterious change from the rough usage, &c., it had been subjected to. The causes were variously assigned to be "percussion," "concussion," "vibration," "jar," "jarring action," "tension," "bending," "deflection," "sudden cooling," "frost," "friction," "heat," "magnetism," &c. Some thought that one of these was sufficient, whilst others maintained that two or three combined were necessary. Now, as all these breakages were *sudden*, the fractures could not possibly have presented the fibrous appearance expected, the latter being produced, as the writer has endeavoured to show, by the *tearing*, not *snapping* asunder, of the various particles.

132. That some of the causes assigned for the change from a fibrous to a crystalline condition should have operated prejudicially on the *tenacity* or *cohesion* of the iron, and so facilitated the rupture, is another and totally different question, which has been somewhat unaccountably mixed up with the former. With one or two exceptions this has been the case with all parties who have treated of the subject, and hence, perhaps, much of the confusion perceptible in the opinions which they have expressed. Another source of confusion, in the writer's opinion, arises from the terms employed by many when merely speaking of good and bad qualities, or of a high and low-priced iron—thus, "a fibrous iron," "a crystalline iron." Throughout the present paper it was thought preferable to describe them thus: a soft as opposed to a hard iron, fine to coarse, ductile to brittle, as seemed most suitable to the particular case. The fractured appearance of the one quality is described either as finely fibrous or finely crystalline, or partly both: the other as coarsely fibrous or coarsely crystalline, or partly both.

133. The writer is not aware that it has ever before been stated, as he has endeavoured to do distinctly, that it is not to any of those agencies named by others, but simply *to the act of breaking*, that are due the different appearances presented to the eye in fractured iron, respectively called fibrous and crystalline, or, as it is termed by some, fibrous and granular, and again, as explained by another (103), "the passage of the iron from a fibrous crystalline state" to "a granular crystalline state." Although Mr. Stephenson did not believe that any change could take place in the structure of iron,

as asserted by others, yet he did not point out what was the cause of the apparent diversity. He showed, however (93), that what appeared to the naked eye fibrous was, under a powerful microscope, essentially a crystalline mass, and again, what appeared extremely crystalline had much the same appearance under the microscope as a fibrous surface to the naked eye; and therefore he could not "conceive a change going on in the structure of iron, as it would involve a change from one kind of crystalline structure to another, which was next to an impossibility." Neither has Mr. Roebling pointed out the cause. He refers (109) to the *strength* being destroyed, and thus ingeniously accounts for it: "Even the best fibrous wrought-iron, when exposed to long-continued vibration under tension, or to tension, bending, or twisting, must inevitably become brittle, because the iron threads and laminæ become loosened in their cinder envelopes. But the cohesion between the iron and its cinder once destroyed, its strength is gone."

134. The varied experiments by which the writer was led to the conclusions stated above, he trusts others, upon a careful examination, will consider satisfactory and conclusive. Mr. M'Connell (90), when replying in support of his own conviction that a change did take place in railway axles from a fibrous to a crystalline structure, "observed that in this, as in some other matters of controversy, it is most difficult to produce full and conclusive proof that iron which is produced of a crystalline character was once fibrous, as we cannot by any experiment show the change visibly taking place," &c. Some objected to the evidence produced in the form of broken railway axles with a crystalline fracture, on the ground that there was no proof they had originally been fibrous; and others went still farther, by stating that they did not believe that any axle which, when broken, proved to be crystalline, had ever been fibrous in its character. Although fully satisfied himself, from his other experiments, the writer thought it extremely desirable to present in the same specimen the two kinds of fracture, so widely different in appearance, in order completely to remove any doubt as to identity that might exist in the minds of any. Hence one of his reasons for making the experiments on the effects of altering the specimen's shape, which have already been referred to under No. 122 of this section.

135. It has already been remarked (127) that the appearance of the crank-shaft specimens varied very singularly, and that they were distinctly different from any of the rolled bars. It occurred to the writer that much additional information as to this and other differences would be gained by immersing a few pieces of the various classes in

dilute hydrochloric acid, which, acting on the surrounding impurities, would expose to view the metallic portion alone for examination. To the beautiful specimens thus obtained he now solicits attention, and craves indulgence whilst attempting to describe some of the most marked features presented. The effect produced by repeated rolling is at once apparent when we compare a highly worked or superior quality with a slightly worked or inferior. In the former the appearance presented by the bar is that of very fine and straight long hairs or threads lying closely together, as shown in fig. 1, Plate XVI.; in the latter, to some extent, there is the same thread-like appearance, but indistinct and wavy, very irregular in size, in some parts lying close, in others far apart, as in fig. 2. Puddled-iron rolled, or wrought-iron in its lowest state, presents more a woolly than a thread-like appearance, as in fig. 3; the latter development seems as if commencing to be formed by the first rolling, the former, or woolly resemblance, to be due to the puddling process. Swedish tilted bars, 264 and 267, present even to the naked eye a beautiful silvery variegated appearance; also Russian bar, 272; the latter dense and very fine. Govan hammered bar, 1119, has the same marked, fine, thread-like appearance, but the threads are not so straight and equal as in the first referred to. Crank-shaft, 793, 794, 1549, are extremely varied, and have a wood-like appearance, as in fig. 5, some portions dense, others porous, with here and there a silvery-looking vein, distinctly different from the other portions; in some places the fibres or threads are seen sideways, in others endways. Armour-plate 798 is like the last, but rather more porous, as shown in fig. 4.

136. It seems surprising to the writer that such a simple mode as that just described, of examining the texture of iron, had not occurred to any of those individuals who have expressed their opinions for and against the supposed change from a fibrous to a crystalline structure during the time of its being in use, as he believes it would have tended to the settlement of the question long ere now. Perhaps it may be asked, Why such a difference, even in appearance, if no actual change in the structure? The writer replies simply thus,—In the case of the fibrous fracture the threads are drawn out, and are viewed *externally;* in the case of the crystalline fracture the threads in clusters are snapped across, and are viewed *internally* or *sectionally.*[*]

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[*] After the foregoing was in type there appeared in *The Practical Mechanic's Journal* (January, 1862) an article entitled "The Annealing Temperatures of Metals, and Crystallization produced by Vibration." The remarks in that issue were confined to the first clause of the title, and conclude thus: "At the commencement of this paper we put in

XI. APPEARANCE OF FRACTURE—STEEL.

137. As nothing, or extremely little, has been written regarding the appearances of fractured steel, the following remarks will be confined to those obtained in course of the present experiments, and recorded in Tables A, C, N, O. They are classified under the following heads, viz.:—

1. Granular.
2. Granular and crystalline.
3. Crystalline and fibrous.
4. Granular and fibrous.
5. Fibrous.

138. These several kinds are represented in Plate II.—Bars: granular, A, B, C; granular and crystalline, D; crystalline and fibrous, E; granular and fibrous, F, G; fibrous (silky), H, I; specimens A and I are respectively the hardest and softest. In Plate III.—Plates: granular, A, B, C; granular and fibrous, D; fibrous (silky), E, F, G, H;

words another class of molecular changes, in virtue of which tyres, axles, cannon, and all things formed of metal are presumed, in course of wear and use, to become deteriorated, weakened, or destroyed, namely, crystallization produced by vibration. We shall reserve the consideration of this, however, to a separate article in a future number. The subject is one of such great practical importance, it is one so little understood, it appears so ill-digested on the part of even some of our leading practical experimentalists on iron, and engineers, and is withal so frequently the subject-matter of ignorant or half-informed remarks in our mechanical journals, and on the part of their correspondents, that we shall best devote to it a separate article." In the continuation of the article in the issue of the ensuing month, allusion is made to the prevailing opinions on the subject of crystallization of metals produced by vibration. The following is an extract:—"We used advisedly these words at the head of this article, although essentially untrue to nature and fact. They are the common 'cant phrase,' we may call it, by which ill-informed men have, for more than twenty years, cloaked their ignorance when called upon to discuss or explain what has taken place when metals have been broken or torn asunder; and by which coroners and juries have been mystified, in cases of loss of life and limb by broken tyres and axles, by a certain class of men delighting to call themselves 'practical,' as though it were not a fact that *the only truly practical man is he who is accurate and well informed in theoretical knowledge.* In this special subject, ignorance, confused and inadequate notions of the molecular constitution of metals in general, and of the changes therein, real or supposed, which happen when they are submitted to strains, steady or variable, or to fracture, is, unhappily, not confined to any class of engineers. Almost every man in the profession who has opened his lips, or put pen to paper on the subject, has shown how unformed and inexact his notions have been." The article closes thus: "We have cleared the foundation, and hope to place the edifice of the just philosophy of the subject before our readers in our next." The discussion of the subject has not been resumed in any subsequent issues of the above journal up to the time of the present portion of this paper going to press. [*For continuation see* Appendix J.]

fibrous (laminated), I, J, K, L. Specimen A is the hardest, and specimen H the softest of the cast-steel rolled plates; whilst specimens I to L are puddled or wrought-steel rolled plates.

139. The conclusions respecting wrought-iron are equally appropriate to steel, viz.,—Whenever rupture occurs *slowly*, a silky fibrous, and when *suddenly*, a granular appearance are invariably the result; both kinds varying in fineness according to quality. The surface in the latter case is even, and always at right angles with the length; in the former, angular and irregular in outline.

140. The colour is a light pearl grey, slightly varying in shade with the quality; the granular fractures are almost entirely free of lustre, and consequently totally unlike the brilliant crystalline appearance of wrought-iron. In order to have specimens with the two combined, for sake of comparison, a number of iron bolts were submitted to the steeling process in a case-hardening furnace, different qualities of iron being used, and several most beautiful fractures were thus obtained. Some of these are given in Plate V.—figs. k, l, m, n, o. The finely granulated ring outside being steel, is nearly free of lustre, whilst the central portion remaining iron, is composed of brilliant crystals. The breadth of ring varies with the quality of iron, being scarcely perceptible in the common quality, but broad and distinctly defined in the Staffordshire charcoal and Yorkshire bars. These case-hardened bolts were referred to in the foregoing Section (123), and will also be in Section XIII.

141. Some examples were adduced to prove that by varying the treatment the same bar of iron may present two very different aspects; so also with steel. Homogeneous rivet metal, Table N, 1041, highly heated and cooled slowly, very soft, drew out and was wholly fibrous; 1038, medium heated and cooled in oil, was 30 per cent. granular; 1037, highly heated and cooled in oil, 95 per cent.; 1042, highly heated and cooled in water, hard, snapped, and was wholly granular. Moss and Gambles' rivet steel, 1034, soft, wholly fibrous; 1033, hardened in oil, 82 per cent. granular, 18 per cent. fibrous; 1030, soft, one-half granular, the other fibrous; 1029, hard, wholly granular. Table O, Homogeneous metal, 1160, 1162, 1164, soft, wholly fibrous; 1159, 1161, 1163, hardened in oil, respectively, 95, 98, 95, per cent. granular.

XII. RATE OF ELONGATION UNDER INCREASING STRAINS.

142. In Tables A to E are stated the extreme elongation of each specimen, the original length of the part stretched, and the amount per cent. of elongation. It was considered, however, of importance to

ascertain, not only the total extension, but also the amount of strain required to produce a perceptible difference in the specimen's length, and the rate of increase, as the subsequent weights were applied. A very accurate quarter-of-an-inch ivory scale, divided decimally throughout its length, was used for reading off the measurements; and as it would have been dangerous to apply the scale directly to the specimen when under severe strain, a large pair of compasses was employed to take the distance between the marks, previously made with a centre-punch. As an example of the mode of noting these observations, take Lowmoor square bar (103, Table B). Area (original) 1·0403 sq. in.; original length of part stretched, 30·4; increase, 7·20 = 23·7 per cent. of the original length.

WEIGHTS ON STEELYARD.

Number,	0	14	16	18	20	22	24	26	27	28	28	28	28	29	29 @ 56 lbs.
											2	4	6	5	5 @ 28 lbs.
														2	4 @ 14 lbs.
															1 @ 7 lbs.
Length,	33·72	33·83	34·00	34·24	34·57	35·00	35·50	36·05	36·40	36·75	37·20	37·60	38·10	39·00	Broke.
Increase,	·00	·11	·28	·52	·83	1·28	1·78	2·33	2·68	3·03	3·48	3·88	4·38	5·28	7·20

143. One specimen in each lot, and the third in the order of testing, was noted; consequently it sometimes happened to be the best, and sometimes the worst, in the set. The relative quality of the specimen can readily be ascertained by referring to the other table, as its index number is given for that purpose. In proof that the little additional time required in testing these had no injurious effect in lessening the amount of breaking strain, as seemed to be imagined by some, it will be found, on going over the 81 bar specimens in table B, whose rate of elongation was observed, that 24 bore the first or highest strain, 21 the second, 20 the third, and 16 the fourth or lowest.

144. These observations are contained in Table L, the specimens being classified and arranged nearly in the order of their respective areas. As the areas varied, and also the lengths, it was necessary for comparison to reduce the progressive strains of this table into lbs. per square inch, and also to convert the observed extensions into decimals of the length. This involved a considerable amount of tedious calculation, which was greatly increased by the steelyard and weights not being decimally proportioned, which of course they would have been if made expressly for testing.

145. The results of these calculations are given in Table M, containing a selection from the various classes. It will be observed, on examining the contents of columns 4 to 24, that the rate as well as the ultimate elongation, column 25, varies not only extremely in

different qualities, but also considerably in specimens of the same brand. The following examples show some of these variations:—

									Ultimate strength.	Ultimate elongation.
Swedish, B F, ...No. 534	30,000	·0200	40,000	·0708	50,000	—	60,000	—	49,032	·2570
Swedish, X, ...533	„	·0200	„	·0540	„	·1670	„	—	50,268	[illegible]
Bradley, (L) ,.............527	„	·0036	„	·0350	„	·0998	„	—	56,004	[illegible]
Bradley, B B, Scrap, ...517	„	·0004	„	·0228	„	·0850	„	—	58,571	[illegible]
Lowmoor, ...504	„	·0030	„	·0190	„	·0600	„	·1420	62,635	[illegible]
Farnley, ...502	„	·0045	„	·0210	„	·0680	„	·1490	64,133	·2647
Govan, ◇,...............511	„	·0017	„	·0160	„	·0680	„	—	59,726	·2717
Ulverston, ...518	„	·0028	„	·0170	„	·0680	„	—	58,000	[illegible]
Ulverston, ...535	„	·0132	„	·0604	„	—	„	—	48,870	[illegible]
Bradley, [illegible] S C, ...505	„	·0040	„	·0200	„	·0690	„	·1720	62,344	·2636
Govan, ✱, ...506	„	·0000	„	·0075	„	·0405	„	·1075	60,722	·1130
Russian, C C NO, ...525	„	·0044	„	·0150	„	·0375	„	—	56,447	[illegible]
Crank-shaft, ...536	„	·0170	„	·0820	„	—	„	—	44,561	·1734
Crank-shaft, ...537	„	·0230	„	·1070	„	—	„	—	43,420	·2461

146. The varied character of the results in Table M are seen at a glance in Plates XI., XII., XIII., containing a series of curves constructed by using as ordinates the numerical contents of columns 4 to 25. It will be observed that in Plate XII., crank-shaft specimen 537, the elongation began to be perceptible at 22,000 lbs., and broke at 43,420; whereas Bowling 550, forged, highly heated, and cooled in water, only began perceptibly to stretch at 43,000, and broke at 76,839.

147. In order to ascertain if the bolts stretched equally throughout their length, several had the distance between the centre points divided into half-inch spaces, as shown on the *dotted* lines in Plate XIV. With a few exceptions the increase was found uniform throughout the length, until very close upon rupture, when they more or less suddenly drew out at one part, as in figs. 1, 3, 4; in some instances at two, as in fig. 2; and in a few exceptional cases at three different places. In this plate the broken bars are shown in outline with the *stretched* spaces marked on the central *full* lines, and the *original* spaces on the *dotted* ones, so that they may be compared.

148. Not only was the lateral contraction at the fracture found to vary extremely, as already noticed in Section VIII, but was also more abrupt in some, as in figs. 1 and 3, more gradual in others, as in fig. 4. This latter peculiarity is also shown by the outline of the specimens in Plates II. and XV., and beautifully illustrated by variations in the elongation curves, Plate XII., as, for example, from a to b in 527, 549, 550.

149. A number of the plate specimens were polished on one side, and a series of circles drawn, which were converted more or less into ellipses on being tested, as shown in fig. 5, Plate XIV.

150. These plates and table show comparatively the marked changes

in extension exhibited in many different qualities; but of course the pieces were too short to observe the minute variations under strains less than from 26,000 to 30,000 lbs. per square inch. It is, however, hoped these illustrations will be acceptable by supplying an existing deficiency in the former respect, and the latter will so far be made up by referring to previous experiments by others, which are only deficient in being too few.

151. Professor Barlow states that the mean extension per ton per square inch in seven experiments on iron bars varied from ·0001082 to ·0000841; the gross mean ·0000956. The strain, which was just sufficient to balance the elasticity of the bar, was found to vary from 11 to 8$\frac{1}{4}$ tons. He remarks,—"We may consider, therefore, that the elastic power of good medium iron is equal to about ten tons per inch, and that this force varies from ten to eight tons in indifferent and bad iron. It appears also (considering ·000095 as representing in round numbers $\frac{1}{10.000}$) that a bar of iron is extended one ten-thousandth part of its length by every ton of direct strain per square inch of section; and consequently that its elasticity will be fully excited when stretched to the amount of one-thousandth part of its length."

152. The late Mr. Hodgkinson made experiments on *two* rods 50 feet long, one ·517 inch diameter, the other ·7517 inch, and found the mean extension per ton per inch was in the first ·0000804, in the second ·0000809, and the rate of extension was remarkably uniform up to 15 or 16 tons.

153. Mr. Edwin Clark gives the result of *one* experiment on "a new wrought-iron bar, 10 feet long and 1 inch square," in the following table. He writes,—"The extension of this material is remarkably uniform up to 15 or 16 tons on the square inch, in proportion to the weight; that is, with 8 or 10 tons the extension is eight or ten times as great as with a single ton. We have the following experimental results in breaking a new wrought-iron bar, 10 feet long and 1 inch square, by a suspended weight increased ton by ton, the bar and weights being reduced, to preserve the uniformity of the table. It will be observed, on comparing columns 2 and 3, that up to 12 tons the observed and calculated extensions are almost identical, by assuming the extension to be $\frac{8}{100.000}$ths of the length per ton per square inch. But beyond this strain the observed extension rapidly exceeds this uniform rate."

Tons.	Observed Extension in terms of the Length.	Computed Extension assumed uniform at $\frac{8}{100000}$ of the Length per Ton per Sq. Inch.	Corresponding Extension in fractional parts of the Length computed at $\frac{8}{100000}$ per Ton per Sq. Inch.	Observed Permanent Set in terms of the Length.	Observed Permanent Set in fractional parts of the Length.
1	·000069	·00008	$\frac{1}{12500}$		
2	·000156	·00016	$\frac{1}{6250}$		
3	·000238	·00024	$\frac{1}{4166}$	·00000213	$\frac{1}{468750}$
4	·000319	·00032	$\frac{1}{3125}$	·00000283	$\frac{1}{350877}$
5	·000399	·00040	$\frac{1}{2500}$	·00000356	$\frac{1}{281030}$
6	·00048	·00048	$\frac{1}{2083}$	·00000427	$\frac{1}{233918}$
7	·00056	·00056	$\frac{1}{1785}$	·00000497	$\frac{1}{201005}$
8	·00064	·00064	$\frac{1}{1562}$	·00000650	$\frac{1}{153846}$
9	·00072	·00072	$\frac{1}{1389}$	·00001201	$\frac{1}{83275}$
10	·00080	·00080	$\frac{1}{1250}$	·00001334	$\frac{1}{74963}$
11	·00089	·00088	$\frac{1}{1136}$	·00003392	$\frac{1}{29484}$
12	·00102	·00096	$\frac{1}{1040}$	·00008368	$\frac{1}{11950}$
13	·00128	·00104	$\frac{1}{961}$	·0002598	$\frac{1}{3846}$
14	·00218 in ten minutes ·00231	·00112	$\frac{1}{893}$	·0011075	$\frac{1}{903}$
15	·00416	·00120	Beyond this weight the permanent set is greater than the computed extension as above.	·002976	$\frac{1}{336}$
16	·00443	·00128		·003175	$\frac{1}{315}$
17	·00934 in ten minutes ·01015	·00136		·008750	$\frac{1}{114}$
18	·01024 in ten minutes ·01212	·00144		·009170	$\frac{1}{109}$
19	·01785 in ten minutes ·02017	·00152		·018590	$\frac{1}{54}$
20	·02124 in ten minutes ·02146	·00160		·019790	$\frac{1}{50}$
21	·02429 in ten minutes ·02472	·00168		·022310	$\frac{1}{45}$
22	·03400 in ten minutes ·03425	·00176		·031933	$\frac{1}{31}$

154. "We may generally assume the ultimate tensile strength of wrought-iron bars at 24, and of wrought-iron plates at 20 tons per square inch, and its ultimate useful strength at 12 tons per square inch; and within this latter limit its extension may be taken at $\frac{8}{100.000}$ths of the length per ton per square inch of section, and its permanent set may be obtained from the table given. Thus, the first extension of the chain used for raising the tubes was ·7968 inch, and the permanent set ·008 inch; but having once used them with this strain, and this permanent set being obtained, on employing them again under the same strain, the extension will only be ·7968 inch—·008

inch, or ·789 inch, and the permanent set will be no further increased. Metal, however, requires a very considerable time to adapt itself to additional strain, or to return again to the diminished length at which it will remain constant after strain, analogous to the length of time found requisite, with astronomical instruments, to allow them to adapt themselves to great change of temperature before they will remain in adjustment. These same laws are applicable both to the compression and the extension of wrought-iron."

155. These *ten* are the only experiments the writer has met with on the *rate* of extension; he will now refer to those on *ultimate* extension. The results of Mr. Lloyd's experiments on 1⅜ inch bars of S C ♛ iron, 1st, To ascertain the effects of four successive breakages, and 2d, "Whether a shorter bar is stronger than a longer one of the same kind and size," are given by Dr. Fairbairn in the two following tables, which have been already referred to in Section VIII.

Distinguishing mark.	First breakage.		Second breakage.		Third breakage.		Fourth breakage.		Reduced from 1·37 to
	Tons.	Stretch in 54 inches.	Tons.	Stretch in 36 inches.	Tons.	Stretch in 24 inches.	Tons.	Stretch in 15 inches.	
		in.		in.		in.		in.	in.
A	33·75	9·125	35·50	2·00					
C	33·75	9·250	35·25	·25	37·00	1·00	38·75	......	1·25
E	32·50	9·250	34·75	1·25					
F	33·25	10·500	35·50	1·12	37·25	·62	40·40	......	1·18
G	32·75	8·500	35·00	1·25	37·5	......	40·41	......	1·25
H	33·75	10·625	36·25	1·87					
I	33·50	8·375	34·50	·62	36·5	1·50			
J	33·50	9·250	36·00	·25	36·75	1·12	41·75	......	1·25
L	32·25	Defective	36·50	1·5	37·75	......	41·00	·81	1·25
M	30·25	Defective	36·50	·62	37·75	·06	38·50	·06	1·25
Mean	32·92	......	35·57	......	37·21	......	40·16	......	1·24
Mean per sq. inch,	23·94	......	25·86	......	27·06	......	29·20	......	·90

156. "It is important to observe that the elongations are not in proportion to the forces of extension; thus, in bar F, the elongation of a bar 54 inches long, with 33·25 tons, is 10·5 inches, giving an elongation per unit of weight and length $= \frac{10{\cdot}5}{33{\cdot}25 \times 54} = {\cdot}0058$; whereas an additional weight of 2·25 tons produces an elongation of 1·25 inches in 36 inches of length of bar, giving an elongation per unit of length and weight $= \frac{1{\cdot}25}{2{\cdot}25 \times 36} = {\cdot}0154$; that is, the elongation in this case is about three times that in the former.

157. "From the experiment on rivet-iron we have a mean elongation, in fourteen experiments, of ·643 inches in 2½ inches, or $\frac{\cdot 643}{2\cdot 5} = \cdot 257$ per unit of length; and in those on S C ♛ bars, we have a mean elongation of ·274, as given in the following table :—

Length between the Nippers.	Breaking strain in tons.	Mean elongation in inches.	Elongation per unit of length.
in.			
120	32·21	26·0	·216
42	32·12	9·8	·233
36	32·35	8·8	·244
24	32·00	6·2	·258
10	32·29	4·2	·420

158. "Hence it appears that the elongation of bars of wrought-iron increases with the decrease of their length; thus, while a bar of 120 inches has an elongation of ·216 inch per unit of its length, a bar of 10 inches has an elongation of ·42 inch per unit of its length, or nearly double what it is in the former case. The relation between the length of bar and its maximum elongation per unit may be approximately expressed by the following formula, viz. :—

$$l = \cdot 18 + \frac{25}{L},$$

where L represents the length of the bar, and l the elongation per unit of length of the bar."

159. It will be noticed that Dr. Fairbairn offers no explanation. The writer, however, hopes to show the reason why the ratio of *ultimate* elongation may, in some kinds of iron, be greater in short than in long bars. This will best be done by referring to the elongation curves; thus, the ultimate extension of 549, Plate XII., is ·2013 of the length, but of this, the distance from b to c, or ·0633, equal to 31·4 per cent. of the whole, is entirely due to fracture, the remainder, ·1380, it is submitted, will be constant whatever may be the length, provided it be of uniform quality throughout. The total elongation in 550 is ·2000; distance b—c, ·0765 = 38·2; remainder, ·1235 constant: also in 527, total, ·2900; distance b—c, ·1290 = 44·5 per cent.; remainder, ·1610 constant, irrespective of length. These three drew out respectively 31·4, 38·2, 44·5 per cent. suddenly before rupture. Next will be given other three where no such drawing-out took place, viz., 514, 525, 531; and consequently the ratio of their ultimate elongation would be unaffected by difference in their lengths. The other Plates,

XI., XIII., also contain several examples of both kinds, which may be examined, but which it will not be necessary to refer to here.

160. The writer will next endeavour to show that Dr. Fairbairn and others have overlooked a second important element as affecting the extension, namely, the area of the specimens. How can the quality be ascertained by comparing the extension, if the respective areas are not also stated? For it surely could not be expected that two bars, although of precisely the same quality and length, would elongate equally if their diameters were, say, 2 inches and ½ inch. It was difficult experimentally to ascertain the exact ratio of the difference due to size alone, as the actual quality in some lots varied very considerably, although all of the same brand, which the following examples from Table B will show:—The mean ultimate elongations will be found in column 21, but for the present purpose they are expressed in units instead of per centages of the length. Glasgow B. Best, 1¼ inch, ·203; 1, ·232; ⅞, ·237; ⅝, ·200. Govan ✱, 1⅛ inch, ·167; 1, ·164; ⅞, ·158; ¾, ·188. Govan B. Best, 1⅛ inch, ·170; 1, ·191; ⅞, ·200; ¾, ·173 and ·169. Govan Ex. B. Best, 1⅛ inch, ·238; 1, ·223; ⅞, ·192; ¾, ·176 and ·173. Govan ◇, 1¼ inch, ·248; 1, ·252; ⅝, ·214. In order to avoid these discrepancies occasioned by variations in the quality, and also by differences in the length, a bar of Govan ◇ 1½ inch diameter was cut into five pieces, of which four were re-heated and reduced in the rolling-mill to 1¼, 1, ¾, ½ inch, and then cut to equal lengths. The results obtained are given in Table N, 1113-1116; 1¼ inch, ·283; 1, ·267; ¾, ·252; ½, ·238. The corresponding breaking strains were 56,869, 57,379, 58,190, 59,708, showing, on the one hand, an increase in strength due to additional rolling; on the other, a decrease in the ratio of extension due to reduction in diameter. This decrease would evidently have been greater had the strength remained uniform. The strength increased 0·9 per cent. in rolling down from 1¼ to 1 inch, 2·3 from 1¼ to ¾, 5·9 from 1¼ to ½ inch; and the ratio of extension decreased 5·7 per cent. in comparing 1¼ with 1 inch; 10·9, 1¼ with ¾; 15·9, 1¼ with ½ inch. The *rate* of extension in these four bars are given in Table M, 542-545; and on referring to Plate XII. it will be found that the curves of 1¼ and ½ inch bars, or 542 and 545, very nearly correspond.

XIII. INFLUENCE OF VARIOUS KINDS OF TREATMENT.

161. The peculiar and invaluable property possessed by steel, of becoming extremely hard after being heated and plunged into cold water, and its capability of being softened down by "tempering"

to the required degree of hardness, seemed for several reasons to be worthy of investigation, to ascertain the influence this hardening had as affecting the *strength* of steel. Tables **N** and **O** contain the results of experiments on bars and plates. For the first trial, six pieces were taken from one bar of "chisel cast-steel," and forged into shape. 1006, Table **N**, was heated and allowed to cool slowly; 1002, heated and plunged into cold water: 1003, same as the last, but tempered to yellow shade by slightly heating; 1005, same as before, but tempered to blue shade; 1004, also heated, cooled as before, and brought to "spring temper" with tallow; 1001, heated and plunged into oil, instead of water. Now, observe the varied results:—1006, soft, bore 121,716 lbs. per square inch; 1002, cooled in *water*, extremely hard, only 90,049 lbs.; 1001, cooled in *oil*, and hard, actually bore 215,400 lbs., or 96⅛ tons per square inch, showing a gain in strength of 77 per cent.; whilst 1002 shows a loss of 26 per cent., 1001 being 2⅖ths stronger than 1002. The other bolts, 1003, 1004, 1005, also show a loss in strength, respectively, of 17·0, 13·8, and 8 per cent. This singular effect of hardening in oil was fully corroborated by subsequent tests, shown in the table. Various qualities of steel were taken, and the degree to which they were heated before immersion was varied, to observe the difference. The following is the per centage of increase in strength, beginning with the hard steels highly heated, and ending with the soft steels slightly heated:—79·0, 77·6, 71·4, 70·9, 65·1, 64·1, 58·5, 57·0, 55·2, 53·2, 44·8, 40·7, 29·5, 24·2, 15·6, 11·8. In a few instances coal-tar was tried, and in some tallow; but the results, although good, were inferior to those with oil, which was of the coarsest and cheapest description. Rivet-steel, heated, and cooled in water, shows a loss in 1035 of 24·4, and in 1042, a loss of 18·5 per cent., confirming the accuracy of the former experiment. Of course the writer was fully aware that oil had previously been used for hardening sundry thin articles; it was not, however, to increase their strength, but because they were distorted by immersion in water.

162. Steel plates were next tried, and are fully detailed in Table **O**. Eleven pieces were heated to various degrees, and hardened in oil: they show the following per centages of gain, viz.:—56·4, 48·2, 43·7, 42·8, 40·6, 40·1, 38·1, 34·4, 30·0, 24·2, 12·8; and it may be remarked that some of these did not break at the small hardened part, but across the soft and broad part of the plate, as attested by the specimens exhibited. Several of these pieces, when under heavy strains, were repeatedly struck with a rivet hammer, causing the whole to vibrate, which proved that they were not only hardened, but

toughened by the treatment; and still further to test this important point, the strain in two instances was temporarily removed, by raising the weights. The plates were thus bent in the middle, but sprung back on being allowed to do so.

163. A few experiments followed on rivetted joints. Eight of the plates were in the usual soft state, and six hardened. The pieces were all cut from one plate ·190 inch thick, and rivet steel, by the same maker, was used. The soft plates, with rivets ·56 inch in diameter, broke across at the rivet holes in two instances, with a loss compared with the solid plate, of 45·6 and 43·5 per cent.; whilst the hardened plate, with rivets ·68 inch in diameter, and with a load only 15·9 per cent. less than that borne by the soft whole plate, had one of the rivets cut through the middle—the *corner* of one plate breaking off left the other rivet in the remaining whole piece. Five of these experiments, with rivets ·43 inch in diameter, were comparatively lost, from the rivets being too small, although larger than those used for iron plates of the same thickness. These are to be considered as mere preliminary experiments, and are only given as such. They are, however, sufficient to show that the hot rivets do not reduce the strength, by affecting the hardness of the plate, which was all they were expected to prove. It will thus be observed that plates hardened in oil, and joined together with rivets, are fully equal in strength to an unjointed soft plate; or, in other words, the loss of strength by rivetting is more than counterbalanced by the increase in strength by hardening the plates in oil. Although scarcely in place here, it may not be considered unimportant to state the amount of strain required to shear or cut through the rivets, compared with that required to pull the bar asunder in the direction of its length. The breaking weight of the bar of rivet steel employed was 86,450 lbs. per square inch of area, and the mean strain required to shear the rivets was 63,796 lbs. per square inch, or 26·2 per cent. less than that needed to pull the bar asunder. This was the mean of the seventeen rivets sheared; the highest sustained a strain of 66,207 lbs.; the lowest, of 61,744 lbs.

164. Table N, 1051-1080, are a series of iron bolts, "case-hardened, which will only be briefly noticed here, as they were prepared principally for their fractures, as mentioned (123, 140), Sections X., XI. It may, perhaps, excite surprise that they should have broken with a less strain than formerly, when wholly iron; but the writer thinks he has satisfactorily accounted for that difference also in the manner already described (123); the superior tenacity of the small proportion of steel being more than counterbalanced by the greater ductility in the remaining portion of iron. Four of these bolts were heated and

cooled in oil, and the four corresponding ones in water; the former were considerably the strongest. Reference letters in description column mark those in the case-hardening furnace for the same length of time, which varied from 14 to 116 hours; but as the heat also varied, no exact comparison can be made.

165. The following remarks refer to the effects produced, as regards the breaking weight and contraction of area, by subjecting iron to various kinds of treatment:—Bowling 1045-1050, Table **N**, were forged down off the same bar as 127, Table **B**; 1045, highly heated, and suddenly cooled in water, bore 76,839 lbs., and only contracted 34·5 per cent. instead of 51·0, with 60·817, as previously, when merely turned down, proving that the iron was made much harder by the treatment. 1047, similarly treated, but not so hard, contracted 44·7 with 71,538; 1046 broke with 71,963 on account of a rent or flaw in the specimen, as indicated by *r*, in column 12. 1048, cooled in oil, contracted 25·7 with 65,934; 1049, 41·6 with 63,341; 1050, cooled in tar, 40·5 with 62,864. 1045 bore 76,839, or nearly the *highest* strain obtained from any piece of iron during the experiments, and was referred to (146) under "elongation" in preceding Section. We will next refer to specimen 1100, which bore the *lowest* strain, viz., 28,578; it was cut crossways out of crank-shaft *A*, was highly heated, and quickly cooled in water like the last, but it snapped very suddenly, with a peculiar creaking noise, quite different from any of the others; 1101, with the same treatment as 1100, but cut lengthways out of crank-shaft *B*, bore 53,331, or nearly twice the strain of 1100, and equal to 20·3 per cent. more than that borne by the piece next to it in the shaft, but which was turned down and tested without having been heated. This additional strain, however, is due to increased hardness, for the contraction of area was only 19·0 with 53,331, instead of 24·3 with 44,311. The hardening effect produced by cooling in water is likewise shown in bolts cut out of armour-plate; 1103 contracted 4·0 per cent. with 36,682, and 1104, 4·0 with 36,147, instead of 5·9 with 34,614, as stated in Table **B**.

166. In order to ascertain how much the iron, as it existed in the crank-shaft, would be improved with additional hammering out, three blocks, 1¾ inch square, were forged down to 1⅛ diameter, and then turned to 1 inch; results as follows:—58,518, 50,906, 49,908, contracting respectively, 17·2, 7·9, 9·8 per cent.; corresponding two pieces merely turned down (294, 295, Table **B**), 44,578, contraction 12·5. Reference to the foregoing bolts have already been made (128) under "appearance of fracture," Section X.

167. Table **N** also contains five bolts, whose collars having failed at

the first trial, were replaced, and again tested; the strain at which they broke was, with one exception, less than that previously borne without rupture. It will, however, be observed that the limit of the specimen's tenacity was nearly reached at the first trial, and the effect of subsequent re-heating was greatly to soften the iron, as proved by the contraction of area. Thus, Govan B. Best was 46·4 with 57,635, instead of 28·9 with 62,849, the mean of 4 bars, same brand and size; Lowmoor, 55·1 with 59,320, and 56·0 with 57,381, instead of 53·1 with 61,798; Farnley, 55·1 with 57,502, and 62·8 with 46,842, instead of 50·6 with 62,886.

168. Some experiments were tried to determine the effects produced by subjecting iron, rolled in the ordinary manner, to the additional process of "cold-rolling;" and to the results, as regards the strength and contraction of area, attention is now directed, reference having previously been made in Section X. (123) to the altered appearance of the fractures. Table O contains the experiments on "Blochairn Best" boiler-plate; lengthways, "cold-rolled" contracted 2·5 per cent. with 88,993 lbs. breaking strain; cold-rolled and afterwards annealed, 13·6 with 50,960; in the ordinary condition, 14·3 with 45,812: crossways, in the same order, 0·0 with 80,643, 7·2 with 48,674, and 7·7 with 43,020. These "cold-rolled" pieces were extremely hard, as shown by the above figures, and by the strips splitting when being cut off at the shearing-machine, also by the broken pieces punched out for rivet holes. Table N, 1081-1090, comprises the experiments on "Blochairn Best" bar; 7 pieces "cold-rolled" varied from 26·8 with 78,466 to 39·3 with 68,718, mean 36·3 with 74,948; 2 pieces cold-rolled and then annealed, 45·2 with 62,285, and 47·6 with 56,477; 1 piece in usual state, 43·1 with 60,637. The shackles shown at fig. 6, Plate I., were used with conical steel wedges to grasp these specimens, instead of forming heads in the usual way, as of course they could not be heated for that purpose. It will be noticed that the greatly increased strain borne by the pieces after being cold-rolled by Mr. Lauth's patent process, was consequent on the iron becoming very much hardened by the treatment. In a printed report by Dr. Fairbairn, the results of three experiments by him are given, viz.:—black bar from the rolls, 58,628 lbs. per square inch; bar turned down to one inch diameter, 60,746; bar rolled cold to one inch diameter, 88,230. The elongation in ten inches being, respectively, 2·00 inches, 2·20, and 0·79. "The first bar was broken in the condition in which it came from the iron manufacturer; the second was a similar bar turned in the lathe; and the third had been subjected to Mr. Lauth's process of cold-rolling. It is obvious that the

effect of the consolidation in the last case was to increase the strength of the bar in the ratio of 10 to 15." Dr. Fairbairn does not attribute the difference to the iron becoming hardened, as stated above, but to the "consolidation of the metal." That, however, cannot be the cause, as the iron is not consolidated by the process, as might seem to be the case from the smooth and greatly improved appearance of the surface, but, in reality, quite the reverse, as will be proved in the remarks under "specific gravities," Section XVIII. Subsequent experiments by Mr. J. Daglish on the strength of iron wire (which in its manufacture undergoes a somewhat similar operation as that of cold-rolling) confirms the accuracy of the writer's experiments given above. He found that whilst wire (No. 11 wire-gauge) held 914 lbs. when in its ordinary state, it only held 508 lbs. after being heated to redness and cooled. Reference will again be made to these experiments in Section XVIII.

169. Nos. 1117-1120 in Table N have been already noticed in Section VIII. (69); 1094, 1095 will be remarked on under "welded joints," Section XVI.; and 1091-1093 under "suddenly applied strains," Section XVII. The results of some experiments to ascertain the effects of the process of galvanizing or tinning on iron plates are given in Table O, Nos. 1121-1134, from which it will be observed that no effects were produced on plates of the thickness experimented on. The consequences, however, might have been different had the plates been extremely thin.

XIV. EFFECTS OF ALTERING SHAPE OF SPECIMENS.

170. The experiments under this section have already been referred to and described in remarks on the appearances of fractured iron, Section X. (122), and illustrated in Plate XV. Having been made, however, for a twofold purpose, attention is now solicited to Table P, which contains the breaking strain and corresponding contraction of the area of the same bars under three conditions, viz., *A*, after being grooved; *B*, after being reduced to the same diameter as the grooved part; *C*, original rough bar. The breaking strain per square inch is given in column 5, and the per centage of difference between original and fractured areas in column 12. In this table the highest breaking strain was borne by Govan hammered bar, viz., *A*, 98,737; *B*, 71,741; *C*, 71,798. The lowest was Port-Dundas Ex. B. Best, viz., *A*, 60,622; *B*, 49,111; *C*, 44,584. The softest iron in this series, or that which contracted most, was Bowling, viz., *A*, 27·84; *B*, 55·56; *C*, 56·44; the hardest was Dundyvan, viz., *A*, 0·00; *B*, 8·03; *C*, 3·88. The relative

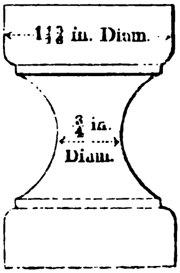
positions of the various specimens under these heads are indicated by the figures in columns 6, 7, 8, and 13, 14, 15.

171. It will be observed that the grooved pieces, *A*, invariably bore the highest comparative strains, and also that they invariably contracted least. The greater comparative strain borne by the grooved pieces is thus fully accounted for, and, at the same time, additional testimony is furnished as to the necessity of always comparing the breaking strains jointly with the contraction of area as enforced in Section VIII., paragraphs 52-54. Those remarks were intended to show that many of the specimens would have borne a much higher breaking strain than they did, were it not for the reduction in their area, owing to the softness of the material. The experiments now under review, it is submitted, are conclusive proof, if such is needed, of the correctness of those statements, as they show that by simply changing the shape of the specimens, so as to interpose an obstacle to their drawing out, a much higher breaking strain was obtained. The writer, in the concluding observations, Section XIX., will consider the use that may be made of the facts elicited.

172. Govan hammered bar, 1201, when grooved, as shown full size in Plate XV., only contracted 13·77 per cent. with the high breaking strain of 98,737 lbs. per square inch, whereas the same piece of iron, 1202, turned down to exactly the same size, but uniform in diameter for 3½ inches of its length (instead of barely one-eighth inch, as in the former), contracted 36·02 with a strain of 71,741 lbs. Thus the former bore 26,996 lbs., or 37½ per cent. more than the latter, *caused solely by the difference in the shape.* The following figures exhibit the extent of this variation in all the pieces tested,—37½, 29¾, 19½, 26¼, 23¼, 20¾, 13½, 6¾, 6¼, 13½, 22¼, 11½, 23¼, 6¼,—the mean of the whole being 18·63 per cent. in favour of the grooved specimens. The amount of breaking strain borne by a specimen is thus proved to be materially affected by its shape—an important influence hitherto unascertained, and even unsuspected by any one, to the best of the writer's knowledge. This is one instance, out of many, that could be produced to show the absolute necessity (and the remark is applicable to many other subjects besides that of the present treatise) of correctly knowing the exact conditions under which any tests are made before we can equitably compare results obtained from different quarters. From the above facts it must surely be evident that we cannot judge of the merits of two pieces of iron or steel by comparing their breaking strains, when one of them was of uniform diameter for some inches of the length, and the other for only a very small portion.

173. The following numerical results of some experiments with the

testing machine in Woolwich Arsenal on Bessemer's Steel, under the direction of Colonel Wilmot, are given by Dr. Fairbairn in his treatise on *Iron*, viz., 162,974, 162,970, 158,899, 156,862, 146,676, 145,512, 136,490; mean breaking strain, 153,677 lbs. per square inch. Now, let us examine the results on Bessemer's Steel in Table A, 27-34. The mean of eight trials is 111,460 lbs.; the highest, 123,165; the lowest, 103,255. If we venture to compare the mean results of the two series, we find the startling difference of 42,217 lbs., or 37⅞ per cent. of higher breaking strain exhibited in the Woolwich experiments as compared with those instituted by the writer. Some individuals, if they happened to make the comparison, would hastily conclude that one of the machines *must* be wrong, and, doubtless, their verdict would be in favour of the *Government* one. The question may, perhaps, however, assume a new aspect if we inquire into the *shape* of the specimens used in both cases. Dr. Fairbairn gives no particulars regarding the form and dimensions of those referred to by him; but, fortunately, we have the desired information from another source. *The Engineer*, 3d Jan., 1862, contains "An Account of Experiments on Puddled Steel, Homogeneous Iron, and Steel Iron, made in Her Majesty's Arsenal at Woolwich," by Mr. W. H. Barlow, who states that the machine "is a counterpart of that employed by the United States Government for ascertaining the strength of cast-iron." He also states—"The very short length of the samples which the machine is capable of receiving, in applying tensile and compressive strains, renders it impossible to arrive at correct conclusions from them in respect of the amount of extension and compression per ton per inch." The form of specimens is represented, half-size, in a wood-cut similar to the one here given, from which it will be observed that the minimum diameter of the specimen occurs at one point only, and, consequently, it presents a still more favourable form for resisting a tensile strain than even the grooved ones of the present series, which, for the reasons already stated in Section X. (121 and 122), were purposely



made with square edges (as shown in Plate XV.), to render them more liable to snap. Having ascertained the shape of the Woolwich specimens, let us now turn to that of the others, by referring to Plate I., fig. 5, for their representation, to Table A, column 1, for their minimum diameter, and to column 20 for the original length of that part which, in this case, is stated to have been 6·8 inches. Having now discovered that a still greater difference in the shape exists between the two sets of specimens now in question than even in those mentioned in preceding paragraph, which was proved so materially to affect the results, the writer thinks no difficulty need be experienced in accounting for the startling discrepancy between his experiments and those made in the Royal Arsenal. The following results were obtained by Mr. Barlow from five samples of each, viz. :—

Puddled Steel by Naylor and Vickers, .	133,054-100,931,	mean,	116,336
Do., melted and cast, Do., .	124,492- 84,652	„	101,753
Homogeneous Metal by Firth & Co., .	115,133- 88,640	„	100,994
Puddled Steel from the Mersey Works, .	109,117- 84,152	„	95,233
Steel Iron from the Atlas Works, . .	71,158- 67,487	„	69,456

A similar striking difference will be found if we compare the Mersey Co.'s puddled steel, referred to here, with that in Table A, 69-74; the mean in the one is 95,233, in the other, 71,486; difference, 23,747; or 33·22 per cent. of higher breaking strain. We are unable to compare any of the other four lots, as either the name of the material or maker is different from any of those in Table A, nor is it necessary, as the two instances adduced will be sufficient evidence to prove the necessity of knowing that the shape of the specimens correspond, before attempting to compare results obtained from different quarters.

XV. COMPARATIVE STRENGTH OF SCREWED AND CHASED BOLTS.

174. On the subject of the strength of locomotive boilers, Mr. D. K. Clark, in the recent supplement to his truly valuable treatise on *Railway Machinery*, refers to some experiments by Mr. Brunel on screwed bolts and nuts of Coalbrookdale iron, and states that the breaking weight per square inch of bolts 1¼ inch diameter was 23·2 tons (51,968 lbs.); 1 inch, 25 tons (56,000); ¾ inch, 27 tons (60,480); ⅝ inch, 32 tons (71,680). He says,—" It is remarkable that the relative strength of the bolts increases as the size is reduced. Thus ⅝-inch bolts, having only one-fourth of the sectional area of 1¼-inch bolts, are proved to have more than one-third the breaking weight; otherwise, the strength rises from 23·2 tons for 1¼-inch bolts to 32 per inch for ⅝-inch bolts. Here lies a new

field of operation for experimentalists; meantime, we suppose we may hazard the explanation that the smaller rods are proportionally the stronger, for the same reason that bars are stronger than boiler-plates, because they are more thoroughly rolled down. That the screwing of a bolt should reduce its tensile strength seems certain. How much? The bolts were not proved to show this, and an estimate can only be formed upon the results of four bolts, of which the shank was 1¼ diameter and the screwed part 1½ inch. The mean breaking weight was 31½ tons, the bolts failing in the shank, equal to 25·2 tons (56,448 lbs.) per inch of section. Thus, the extra size of the screwed part added 2 tons (4,480 lbs.) per inch to the strength of the bolt; and, inversely, it may be inferred that the screwing of 1¼-inch bolts deducts 8 per cent. of the strength of the entire bolt. The deduction may amount to 10 or 12 per cent. for smaller bolts."

175. It is evident from the above quotation that there has existed the want of sufficient ascertained data on the subject of this section, and it is hoped that the contents of Tables Q and R will prove acceptable in supplying this deficiency. The pitch of screw and depth of thread of the various sizes tested were all according to the Whitworth gauge, being that adopted by the Admiralty for all the engine bolts required for the Royal Navy, and now generally recognized as the standard. Both ends of the bolts were screwed, as shown with the testing shackles in fig. 6, Plate I., and loose collars were used to suit the different diameters.

176. Reference to Table Q has already been made (123) when remarking on the appearance of the fractures, and attention was called to the difference produced in the fractures from using old and new dies in the screwing of the bolts. It is now wished to direct attention to the also somewhat singular difference in the breaking strain of the two sets respectively. After a very careful examination of the bolts no difference in shape or size could be detected; the diameters both at top and bottom of screw-thread corresponded exactly; all the bolts were screwed by one person, without any more care being taken than usual in their preparation; the two machines were likewise of similar construction, and by the same makers, the only difference being that the one had been in constant use for some years, while the other was nearly new. It is submitted that this difference in the dies had the effect of considerably hardening the surface of the iron when the old and blunt ones were used, and only slightly when the new dies were employed, the formation of the screw-thread in the latter case being more due to cutting out than in the former. The correctness of this conclusion was further confirmed by taking other pieces off the same

bars, and "chasing" or cutting the screw in a "self-acting lathe," where, as there were no dies employed, there could be no hardening effect; and on referring to Table Q it will be seen that these bolts bore still less, though the difference was but slight, than those operated upon by the new dies; the per centage of this difference being for ◇ Govan ◇ 2·55, Glasgow B. Best 3·92 and 4·46, Bagnall ♛ J B 8·29, or an average of 4·81. Lowmoor 1-inch bolts, screwed with the old dies, broke with 55,158 lbs. per square inch; whereas those screwed with the new broke with 42,647, or 22·6 per cent. less; Glasgow B. Best 1 inch, old dies, broke with 45,294; new dies, 38,856, or 14·2 per cent. less; Glasgow B. Best ⅝ inch, old dies, 51,101; new dies, 43,600, or 14·7 less; and ◇ Govan ◇ ⅝ inch, old dies, 53,855; new dies, 47,846, or 11·2 less; the mean difference of the whole being 15·7 per cent. less with the new than with the old dies.

177. Let us now compare bolts of various sizes, to find if there can be such a vast difference in the comparative strength of 1¼-inch and ⅝-inch bolts as in those referred to by Mr. Clark. ◇ Govan ◇ 1¼ inch, new dies, broke with 45,911 per square inch; ⅝ inch, 47,846; difference, 4·21 per cent. in favour of the latter; the same bars unscrewed broke, respectively, with 57,598 and 58,199; difference, 1·04 per cent. Glasgow B. Best 1¼ inch, 41,161; ⅝ inch, 43,600; difference, 5·92 per cent.; the same bars unscrewed, 54,579 and 59,300; difference, 8·65. The mean difference between 1¼ and ⅝ inch, in the present series, amounts with ◇ Govan ◇ to 4·21, and with Glasgow B. Best to 5·92, or only an average of 5·06 in favour of the smaller size, instead of the enormous difference of 38·0 per cent., as in the quoted experiments. A part of this difference might be accounted for by supposing the proportions of the depth of the screw-thread to the diameters had not been so nicely proportioned in Brunel's experiments as in the present; that the dies of the 1¼-inch might have been sharper than those used for the ⅝-inch bolts. It is to be regretted that the strength of the same bars unscrewed had not at the same time been ascertained, as there might have been a greater difference in the quality of the iron forming these two sizes than was proved to be the case in the present series; yet, notwithstanding, it seems scarcely possible that there really could have been such a difference as that stated. The suspicion of an essential error pervading these experiments is materially strengthened by the circumstance that whilst the ⅝-inch bolt is reported to have borne a strain of 32 tons per square inch, the ¾-inch bolt bore a strain of 27 tons. According to this statement, then, we find an increased breaking strain of 5 tons in the ⅝-inch above the ¾-inch bolt. Such a rapid increase is quite incredible, more especially when we find the

¾-inch bolt bearing an additional strain of only 2 tons above that of the 1-inch bolt.

178. In Table Q, column 13, the amount of reduction in the strength by screwing is individually stated for the whole of the 180 bolts experimented upon in per centage of the original bar; the mean of the various lots is shown in column 14, and the equivalent diameter of an unscrewed bar of the same quality in column 16.

179. Each piece forming lot 1406-1420 was tested three times, the broken end only being re-screwed. The order in which they were tried is shown by figures in description column. The highest results were obtained in two cases at the first trial, in one case at the second, and in two at the third; the lowest, in two instances, occurred at the third, one at the second, and two at the first trial, showing that the one screw was not necessarily injured with the strain that broke the other.

XVI. RELATIVE STRENGTH OF WELDED JOINTS.

180. The experiments made to ascertain the strength of welded joints will be found fully detailed in Table S. The pieces were cut through the middle, and then scarfed and welded in the ordinary manner by the same smith who prepared the bolts for the other experiments, and a few by a chain-maker, for comparison. The results varied greatly,—fourteen, as operated on by the smith, show a loss, compared with the original whole bar, from 4·1 to 43·8 per cent., the mean loss being 20·8 per cent.; four by the chain-maker, from 2·6 to 37·4; mean, 15·1 per cent. Of the former, four broke solid, away from the weld; eight, partly through solid portion and partly at the weld; two separated at the weld. Of the latter, two broke solid, one broke partly solid and partly at the weld, and one gave way at the weld. It will be noticed that different sizes and also different qualities were used, but the results were alike uncertain, and are further proof of the correctness of the following observations by the distinguished engineer, James Nasmyth, Esq., which appeared in *The Engineer*, 8th March, 1861, a considerable time after the experiments were made:—

"Of all the processes connected with the working of malleable-iron there is none that has a more intimate relation to the security of life and property than that of 'welding,' or the process by which we are enabled to unite together, in one mass, the several portions of malleable-iron, of which the generality of works in that material are formed. Every single link in a chain-cable, every wheel-tyre in a railway train, directly owes its trustworthiness to the manner in which the process of welding has been performed, in so far as that any imperfection in any one single member of the set of cable links or railway wheel-tyres may involve a most fearful loss of life, of which, of late years especially, we have had such distressing and melancholy experience.

"It is with the most earnest conviction of the vital importance of the process of welding, by reason of its close relation to the security of life and property, that I am anxious to offer a few remarks, based on long and intimate acquaintance with the process in question, and on those conditions that conduce to its perfect performance, which remarks, I am fain to think, if read with due care and consideration by those who are more specially concerned with the practice of the process of welding iron, may in no small degree tend to render less frequent those fearful and distressing catastrophes of which recent records of ship and railway disasters furnish such sad evidence.

"In order to render more clear the following remarks as to the cause and most certain means of the prevention of defective welding, it may be as well, at the risk of a little tediousness, to explain the nature of the process of welding iron, which consists in inducing upon malleable-iron, by means of a very high heat, a certain degree of adhesiveness, so that any two pieces of malleable-iron, when heated to the requisite degree, will, if brought into close contact, adhere or stick together with a greater or less tenacity, according to the amount of force applied to urge them into close contact. . . . .

"It is, therefore, to the means of thoroughly expelling this vitrified oxide from between the surfaces of the iron where the welded junction is to take place that we must direct our attention; for so long as any portion of this adhesive viscid substance is permitted to exist and interpose itself between the surfaces we desire to unite by welding, no sound or trustworthy junction can take place, and once it has made a lodgment no after-heating or hammering, be it ever so severe, will cause its thorough expulsion. It is, therefore, to the thorough expulsion of the vitreous oxide in the first stage of the welding that we must direct the most careful attention; and it would, in no small degree, tend to bring to an end those fearful accidents of which defectively-welded iron-work is so fertile a cause, if all those who are specially and practically concerned with the superintendence of workmen entrusted with the performance of this vitally important process would see to the use and practice of the truly simple means which I am about to describe.

"As I have before said, the chief cause of defective welding arises from portions of the vitreous oxide of the iron being shut up between the surfaces at the part presumed to have been welded, and that, besides the impossibility of ascertaining, in the majority of cases, after the process of welding has been gone through, whether or not this vitreous oxide has been thoroughly expelled, and the surfaces at the welding brought into perfect metallic union, and that no after-heating or hammering can dislodge the vitreous oxide when once it has effected a lodgment, our best and only true security is to form the surfaces of the iron at the part where the welding is desired to take place, so that when applied to each other, when at the welding heat, *their first contact with each other shall be in the centre of each.*"

181. Table **S** also contains two steel bars welded at the makers' works, the result still more unsatisfactory,—one showing a loss of 45·0, the other 59·6 per cent.; whilst other two parted at the weld during the operation of forming the heads, previous to testing. It was mentioned under "preparation of specimens" (15), that at the commencement of the experiments several attempts were made to form heads on the steel specimens, in the same manner as on the iron, by welding on rings; but as they either failed at the weld, or the steel was found to be burned, that method was abandoned.

182. With the view of ascertaining the effect of heating iron to the welding point, and then allowing it to cool slowly without being hammered, an experiment was made with a bar of Glasgow B. Best, the results of which are stated in Table **N**, 1095. Although its breaking strain was nearly the same as that borne by another piece, 1094, off the same bar, in the ordinary condition, yet it will be found that the ductility of the iron had been injured by the high temperature and want of hammering; for we find that instead of 42·2 per cent. it only contracted 27·8, or 34 per cent. less than the latter.

XVII. SUDDENLY APPLIED STRAINS.

183. In all the preceding experiments the weights were applied gradually until rupture took place. The writer now wishes to direct attention to another series, in which the weights were applied suddenly. Before remarking on the results obtained, it will be proper to explain the mode of operation in so far as it varied from that already described in Sections II. and V., in relation to the other experiments. The same testing apparatus was employed, but the trigger represented in Plate XVI. was substituted for the rope sling *r*, fig. 1, Plate I. The steelyard was raised to the required position, as before, by means of a crane, from the chain-hook of which hung the trigger; but instead of lowering the crane-chain, after fixing the specimen in the

machine, it was kept stationary. When the required number of weights were attached to the end of the steelyard, the screw *l*, Plate I., was turned round so as to bring a slight strain on the specimen, and then, by a sudden pull of the rope from the trigger, the steelyard was disengaged, and consequently the whole weight instantaneously transferred, without jerk, from the crane-chain to the specimen. The numerical results will be found stated in Table T, column 12 and 13 of which contain respectively the index number and the breaking strain when gradually applied, column 4 the amount of strain which was suddenly applied, and column 14 the amount of sudden strain expressed in per centage of gradual strain; whilst the remarks in column 15 show whether the load caused the breakage of the specimen or not.

184. In Section X. (124) the writer has remarked on the change in the appearance of the fractures as one of the effects produced by the strain being suddenly instead of gradually applied, and he now directs attention to the other effects produced.

185. In order to ascertain the amount of strain just sufficient to produce rupture, experiments were made with various loads; in some the load was more than sufficient, in others less. If we extract from Table T the lowest strain that caused rupture, and the highest strain which the specimen bore without breaking, and then take the mean, we shall obtain approximately the amount of strain desired: thus

		Broke with			Unbroken with			Mean	
1503	Bradley (L),	49,909 lbs.,	or 89·1	per cent.	1504,	48,874 lbs.,	or 84·6	49,392 lbs.,	or 86·8
1509	Bradley ≌ S C,	50,145 „	80·4	„	1508,	48,874 „	78·4	49,509 „	79·4
1513	Lowmoor,	48,874 „	82·4	„	1514,	46,842 „	79·0	47,858 „	80·7
1520	Do.,	48,874 „	81·3	„	1519,	44,810 „	74·6	46,842 „	78·0
1524	Glasgow B. Best,	46,842 „	78·6	„	1523,	42,778 „	71·8	45,810 „	75·2
1534	Do.	47,734 „	81·8	„	1535,	46,658 „	80·0	47,196 „	80·9
1536	Do.	50,835 „	91·2	„	1537,	49,948 „	89·6	50,391 „	90·4
1547	Crank-shaft,	35,923 „	82·1	„	1548,	34,945 „	79·8	35,434 „	81·0

The average of the whole is 81·5, or a less strain by 18·5 per cent. than that borne when the strain was gradually instead of suddenly applied.

186. Some persons objected to the writer's mode of applying the weights in the former experiments, on the allegation that the specimens would have borne more if the weights had been *very quickly applied*. It was somewhat difficult to understand the bearing of such an argument, but he was nevertheless perfectly willing to test the truth of the statement by actual experiment. Under the supervision of the gentlemen in question, a beam-scale was accordingly substituted for the chain and hooks (shown in Plate I.), into which a number of weights were placed, the lever was then raised to the height they

deemed sufficient, and the specimen having been properly placed, the crane was lowered, causing the specimens in some instances to break at once, in others, on more weights being *quickly* added. The writer supposes the results were considered *very satisfactory;* at least, he heard no more objections as to his mode of applying the weights; in fact, they were only additional confirmatory evidence of his experiments on "suddenly applied strains," made more than two years previous. We may also revert to Section XII. (143), where it was shown that the little additional time required in testing the specimens had not acted injuriously, as some seemed to imagine, in lessening the amount of their breaking strain.

187. We will now compare the respective effects of a sudden and gradually applied strain as regards the contraction of the specimens' area:

					Sudden.		Gradual.		
1501	Bradley (L),	Load,	108·6	Contracted	55·1	instead	of 60·3	difference	5·2
1502	Do.,	„	105·3	„	56·4	„	60·3	„	3·9
1503	Do.,	„	89·1	„	60·3	„	60·3	„	0·0
1505	Bradley B B Scrap,	„	95·1	„	43·8	„	51·0	„	7·2
1506	Do.,	„	88·9	„	48·2	„	52·4	„	4·2
1507	Bradley ♛ S C,	„	79·2	„	4·4	„	15·1	„	10·7
1509	Do.,	„	80·4	„	46·6	„	45·1	„	1·5
1510	Lowmoor,	„	94·4	„	48·2	„	51·0	„	2·8
1511	Do.,	„	82·4	„	48·2	„	53·7	„	5·5
1513	Do.,	„	82·4	„	51·0	„	53·7	„	2·7
1517	Do.,	„	81·3	„	48·2	„	53·7	„	5·5
1520	Do.,	„	81·3	„	48·2	„	53·7	„	5·5
1524	Glasgow B Best,	„	78·6	„	43·8	„	43·8	„	0·0
1526	Do.,	„	81·4	„	42·6	„	41·1	„	1·5
1529	Do.,	„	83·7	„	24·3	„	32·8	„	8·5
1530	Do.,	„	93·8	„	3·9	„	32·8	„	28·9
1531	Do.,	„	94·5	„	11·8	„	41·4	„	29·6
1532	Do.,	„	87·2	„	33·3	„	41·4	„	8·1
1533	Do.,	„	87·2	„	46·0	„	41·4	„	4·6
1534	Do.,	„	81·8	„	46·0	„	41·4	„	4·6
1536	Do.,	„	91·2	„	42·2	„	44·2	„	2·2
1543	Do.,	„	97·8	„	29·5	„	42·4	„	12·9
1544	Do.,	„	90·0	„	38·1	„	42·4	„	4·3
1545	Bagnall ♛ J B,	„	88·1	„	6·3	„	7·9	„	1·6
1546	Crank-Shaft,	„	88·4	„	19·0	„	23·1	„	4·1
1547	Do.,	„	82·1	„	22·4	„	23·1	„	0·7

188. It was shown (124) that the variations in the appearances of the fractures under sudden strains fully corroborated the accuracy of the former experiments under gradual strains, and if we examine the results as regards the contraction of area, we shall find that they also are confirmatory of the accuracy of both sets of experiments,

although they may appear in some respects antagonistic. Thus, it is submitted, the great difference which occurs in Glasgow B Best, 1530 and 1531, viz., 28·9 and 29·6 per cent., was due to the per centage of the load, viz., 93·8 and 94·5, being greatly in excess of that just sufficient to cause rupture. The specimens accordingly broke very suddenly, without having time to contract in area. In proof, take other two pieces, respectively from the same bars, viz., 1529 and 1534, with loads equal to a per centage of 83·7 and 81·8; the difference is only 8·5 and 4·6, instead of 28·9 and 29·6. Again, if we take another piece, viz., 1524, with a strain just sufficient to break it, viz., 78·6 per cent. of its breaking strain, when gradually applied, we find it contracted 43·8 per cent., or exactly to the same extent as formerly. Although Bradley Ⓛ 1501 was loaded fully a quarter more than that sufficient to cause rupture, yet, owing to the superior fineness and softness of the material, it drew out most beautifully, and yielded a result, in the contraction of area, only slightly less, viz., 55·1, instead of 60·3, formerly obtained under the strain when gradually applied.

189. Frost being considered to act injuriously on the strength of iron, some experiments were made during the severe weather in Dec., 1860, to ascertain its effects. A bar of Glasgow B Best, ¾ inch diameter, was converted into ten bolts, in the ordinary way, six were exposed all night to intense frost, and tested in the morning with the thermometer at 23° Fah. The other four were kept in a warm place, and carefully protected during testing. Three were tested with gradual, and seven with sudden strains; Tables N and T contain respectively the results. On referring to Table N, 1091-1093, it will be found that when the strain was gradually applied there was very little difference between the specimen tested in the ordinary condition and the two that were frozen; the former bore 55,717, the latter 54,385; difference, 1,332 lbs., or 2·3 per cent. less. The difference under sudden strains is somewhat greater, viz., 3·6 per cent. less when frozen. The load just sufficient to cause rupture was in the one case somewhere between 50,835 and 49,948; in the other, between 49,060 and 48,109; the mean in the one instance being 50,391, in the other, 48,584; difference, 1,807 lbs., or 3·6 per cent. The writer regrets that other duties prevented him from carrying out his intention of repeating these experiments with bars of various qualities. It will be noticed that the bar tested happened to be of superior quality; had it been of a coarser description, the difference when frozen might have been much greater. The frozen bolts were coated with a thin layer of ice, for the purpose of better observing the effects produced. In specimen No. 1093, Table N, with strain slowly applied,

the ice gradually became opaque and white, and just before breaking it resembled hoar frost. In No. 1542, Table T, under sudden strain the ice remained transparent, and the instantaneous stretching of the specimen was most beautifully exhibited by the ice cracking and forming a series of complete rings. In No. 1539 the strain was greater than in the last, and caused the rupture of the specimen; the heat thereby generated was apparent by the ice melting, and in the formation of vapour.

XVIII. SPECIFIC GRAVITIES.

190. The specific gravity of the various specimens contained in Table U were ascertained by carefully weighing them first in the air and then in water, and dividing the first weight by the difference; thus, No. 1601, when weighed in the air, was 12,230 grains, when in water, 10,654·5 grains; then 12,230 ÷ 1575·5 (the difference or loss in weight) = 7·7626 specific gravity of that specimen, water being 1·0000. The water employed was not distilled, but from Loch Katrine, which is so free from foreign matter that, for practical purposes, it may be regarded as pure. Its temperature was kept uniform at 60 degrees, and a very fine wire was used for suspending the specimens.

191. It will be observed, on looking over Table U, that the specific gravity generally indicates pretty correctly the quality of the specimen. In the pieces that were weighed the specific gravities were found to range as follows:—

Steel Bars, rolled,	highest	7·8303,	lowest	7·6698,	mean	7·7677,	number	16
Steel Plate, „	„	7·8280,	„	7·6237,	„	7·7570,	„	16
Iron Bars, foreign,	„	7·8088,	„	7·7206,	„	7·7764,	„	10
Iron Bars, rolled,	„	7·7626,	„	7·5333,	„	7·6628,	„	48
Angle-Iron, „	„	7·7310,	„	7·5297,	„	7·6006,	„	10
Iron Plates, „	„	7·7419,	„	7·5005,	„	7·6287,	„	26
Iron Shaft, hammered,	„	7·6585,	„	7·6077,	„	7·6307,	„	6
Iron Plate, „ „	„	7·6303,	„	7·5965,	„	7·6134,	„	2
Iron Bar, „ „	„	7·7652,	„	7·7630,	„	7·7641,	„	2
Puddled-Iron, rolled,	„	7·5381,	„	7·2898,	„	7·4276,	„	8

192. Dr. Robison, in *The Encyclopædia Britannica* (vol. xx., p. 756) remarks, "It is a very curious and inexplicable fact, that by forging a metal, or by frequently drawing it through a smooth hole in a steel plate, its cohesion is greatly increased. This operation undoubtedly deranges the natural situation of the particles. They are squeezed closer together in one direction, but it is not in the direction in which they resist the fracture. In this direction they are rather separated to a greater distance. The general density, however, is augmented in all

of them except lead, which grows rather rarer by wire-drawing; but its cohesion may be more than tripled by this operation. Gold, silver, and brass have their cohesion nearly tripled; copper and iron have it more than doubled. In this operation they also grow much harder. It is proper to heat them to redness after drawing a little. This is called *nealing* or *annealing*. It softens the metal again, and renders it susceptible of another drawing, without risk of cracking in the operation." The writer's experiments on iron "cold-rolled," already referred to in Section XIII. (168), confirms the accuracy of the above statement in so far as regards the increase in cohesion and in hardness. Dr. Robison, however, was in error in stating that "the general density is augmented;" and the similar statement by Dr. Fairbairn, that "the iron is consolidated" by the process, will now be shown to be incorrect in point of fact. The specific gravity of a bar (1687) in the ordinary condition was 7·6360; the mean specific gravity of four pieces (1690-1693) cold-rolled was 7·5824; that of two pieces of boiler-plate (1730, 1731) in the ordinary condition was 7·5664; and that of two other cold-rolled pieces (1732, 1733) was 7·5392. Instead of an *increase* we have a *decrease* in the specific gravity of 0·70 per cent. in the bar specimens, and 0·36 per cent. in the plate specimens, produced by the process of cold-rolling. The writer will now give proof of this fact in another form, by comparing the cubic contents of a bar previous to and after undergoing the process, thus,—

Ordinary state, diameter ·825, area ·5810, length 35·06, cubic contents 18·6168
Cold-rolled, „ ·764, „ ·4584, „ 40·94, „ „ 18·7669

We have here an *increase in the bulk* of this specimen of 0·1501 cubic inches, or 0·86 per cent.

193. Just a year after these experiments on cold-rolled iron were made there appeared in *The Engineer*, 1st Feb., 1861, a paper by Mr. John Daglish, "On the Cause of the Loss of Strength in Iron-wire when Heated." He refers to Dr. Fairbairn's experiments on cold-rolled iron, and quotes his opinion that the great increase in the tensile strength of this description of iron was owing to "the effect of consolidation," and that, when passed through a fire, "many of the pores, before consolidated, must be again opened, there arising a consequent diminution of the strength previously gained." Mr. Daglish proceeds to remark, "Ordinary iron-wire is drawn cold, and, passing through a similar process, may be considered to be similar in nature and structure to cold-rolled iron, and it is also spoken of by eminent authorities as becoming condensed and hardened after passing

a few times through the draw-plate, and that its greatly increased tensile strength is owing to this consolidation.

"During late years much attention has been paid to the improvement of iron, not only by refining, de-carbonizing, and re-carbonizing, but also by adding small quantities of chemical substances, and considerable success seems to have been attained; at the same time, in some cases, the quantity of foreign matter used is so minute as to create surprise at the extraordinary results stated to have been arrived at by its use; and, again, careful analysis has proved that some excellent qualities of iron contain a considerable quantity of substances which were previously considered to be most prejudicial. Under these circumstances it will be interesting rightly to ascertain the cause of the great variation in the tensile strength of iron-wire after heating, for it is still the same material, without any change in its chemical nature, or apparently in its bulk.

"The generally received opinion of consolidation does not seem to the writer to be well founded. This ought to result, perhaps, to a greater extent, when the iron is treated in a heated and softened state, than when drawn or rolled cold and hard, for it is natural to suppose that it would be equally readily compressed when in the former state, and it has still to undergo the contraction of cooling, which exerts a far greater consolidating force than any merely mechanical method.

"If there is any permanent expansion in cold-rolled more than in hot-rolled iron after being heated red, the specific gravity of the body taken after and before ought to show it; and to find this the following experiments were made:—

1.—Common Rolled Iron.—A piece cut off a 3-inch rolled bar.

Before heating,	7·600	7·549
After heating,	7·602	7·554
Increase,	·002	·005

2.—Common Rolled Iron.—A piece of ¼-inch bar.

Before heating,	7·582	7·579	7·579
After heating,	7·592	7·590	7·594
Increase,	·010	·011	·015

3.—Common Rolled and Hammered Iron.—A piece cut off a large common bar, and reduced by hammering whilst hot to a ¼-inch rod.

Before heating,	7·611	7·625
After heating,	7·589	7·600
Decrease,	·002	·025

4.—Common Forged Iron.—Cut off a piece of forged iron, and reduced by hammering whilst hot to a ¼-inch rod.

Before heating,	7·737	7·756
After heating,	7·696	7·737
Decrease,	·041	·019

5.—Common Iron Wire, ⅛-inch.

Before heating,	7·650
After heating,	7·669
Increase,	·019

6.—Round Hard-drawn Wire, ¼-inch.

Before heating red,	7·577	7·589	7·571
After heating red,	7·555	7·580	7·559
Decrease,	·022	·009	·012

7.—Common Steel Wire, ⅛-inch.

Before heating,	7·810
After heating,	7·814
Increase,	·004

8.—Blistered Steel.

Before heating,	7·829	7·827
After heating,	7·819	7·819
Decrease,	·010	·008

9.—Cast Steel.

Before heating,	7·804	7·833
After heating,	7·808	7·838
Increase,	·004	·005

"It appears from the above that heating does not alter the original specific gravity to the extent of more than 1-300th, and although pretty regular for the same description of iron, it sometimes causes an increase and sometimes a decrease in the specific gravity of different qualities of iron, and no regular law is exhibited.

"It will be observed that the specific gravity of hard-drawn wire (6 = 7·58) is less than that of forged iron (4 = 7·74), showing that in forging the iron is more consolidated than in drawing, although its tensile strength is much less.

"In the former experiments a piece of ¾-inch chain, made from a bar of carefully forged scrap iron (spec. grav. = 7·74), broke on a strain of 15 tons; whilst similar chain, made out of a bar of best rolled iron (S C crown) (spec. grav. = 7·56), bore 24 tons.

"It must be concluded, therefore, that 'consolidation or condensation' is not the cause of the greatly increased strength of cold-drawn wire, nor is the injurious action of red heat owing to 'opening the pores,' but that these effects are owing to some change in the molecular structure of the iron, not accompanied by change of bulk, or otherwise sensibly apparent."

194. It has also been imagined by some that the density increases when a bar is subjected to severe tensile strain, as, for example, by the late Robert Stephenson, Esq., who, in course of the discussion to which reference was made in Section X. (83-97), observed,—"It must be borne in mind that the section of the bar was diminishing, and its density increasing, during the stretching." The results of the writer's experiments to determine this point will be found in the table. The specific gravity of a bar of Bowling iron (1682) in the ordinary condition was 7·7630; when reduced in diameter from 1·00 to 0·89 inch, by drawing out lengthways, the specific gravity was found to be 7·7093, or a decrease of 0·69 per cent. Lowmoor (1684) in its ordinary condition was 7·7470; when reduced from 1·00 to 0·91 inch its specific gravity was 7·6605, or a decrease of 1·11 per cent.; and in another piece reduced from 1·00 to 0·89 inch it was 7·6506, or a decrease of 1·23 per cent. The specific gravity of Blochairn Best (1687) in the ordinary condition was 7·6360; when reduced from ·83 to ·78 inch it was 7·5829, or a decrease of 0·69 per cent.; and in another piece reduced from ·83 to ·73 inch it was 7·5553, or a decrease of 1·06 per cent. It will be observed that in two cases the bars contracted to the same size, viz., ·89 inch, but the decrease in the density was, in one case, 0·69, and in the other, 1·23 per cent. In the first instance the diameter contracted at one part only, whereas in the other the diameter was nearly uniform throughout the length.

195. We will now proceed to compare the specific gravities of various sized bars, to ascertain if the rolling down whilst hot, in the usual manner, increases the density or not. Glasgow B. Best, four pieces 1¼ inch diameter (1623-1626) yielded a mean of 7·6530; four pieces ⅝ inch (1619-1622) yielded a mean of 7·6578, showing a very slight increase. Govan ◇, four pieces 1¼ inch (1605-1608) showed a mean of 7·7201; four pieces ⅝ inch (1609-1612) showed 7·6975, or a decrease of 0·29 per cent. Being somewhat surprised with the latter result, and wishing further proof, the writer next weighed the five pieces (1677-1681) which were originally off one bar, but which, for the purpose of ascertaining the effects of additional rolling, had been reduced in the rolling-mill to various sizes. The specific gravity of the 1¼-inch bar was 7·7290, of the 1-inch bar, 7·7222, of the ¾-inch bar, 7·7018, and of the ½-inch, bar, 7·6850, showing a decrease in the

density as they became reduced in diameter. It will be noticed, however, that the specific gravity of the 1½-inch bar was somewhat less than that of the 1¼-inch bar, being 7·7200, instead of 7·7290.

196. The most highly converted steel does not, as some may imagine, possess the greatest density, the hardest steel (1738-1739) being only 7·8152; whereas the softest (1736-1737) is 7·8220. The specific gravity of puddled-steel is less than some of the superior kinds of wrought-iron.

XIX.—CONCLUDING OBSERVATIONS.

197. In this, the closing section, the various conclusions at which the writer has arrived in course of this inquiry are presented collectively, with the numbers for reference to preceding paragraphs where they are stated more fully. The conclusions are as follow:—

1st. The breaking strain does *not* indicate the quality, as hitherto assumed, (51, 53.)

2nd. A *high* breaking strain may be due to the iron being of superior quality, dense, fine, and moderately soft, or simply to its being very hard and unyielding, (52—54.)

3rd. A *low* breaking strain may be due to looseness and coarseness in the texture, or to extreme softness, although very close and fine in quality, (52—54.)

4th. The contraction of area at fracture, previously overlooked, forms an essential element in estimating the quality of specimens, (52, 68, 73, 167.)

5th. The respective merits of various specimens can be correctly ascertained by comparing the breaking strain *jointly* with the contraction of area, (54, 74, 171.)

6th. Inferior qualities show a much greater variation in the breaking strain than superior, (54, 56.)

7th. Greater differences exist between small and large bars in coarse than in fine varieties, (57.)

8th. The prevailing opinion of a rough bar being stronger than a turned one is erroneous, (58, 69.)

9th. Rolled bars are slightly hardened by being forged down, (59.)

10th. The breaking strain and contraction of area of iron plates are greater in the direction in which they are rolled than in a transverse direction, (61.)

11th. A very slight difference exists between specimens from the centre and specimens from the outside of crank-shafts, (62.)

12th. The breaking strain and contraction of area are greater in those specimens cut lengthways out of crank-shafts than in those cut crossways, (62.)

13th. The breaking strain of steel, when taken alone, gives no clue to the real qualities of various kinds of that metal, (74.)

14th. The contraction of area at fracture of specimens of steel must be ascertained as well as in those of iron, (74.)

15th. The breaking strain, *jointly* with the contraction of area, affords the means of comparing the peculiarities in various lots of specimens, (74, 75.)

16th. Some descriptions of steel are found to be very hard, and, consequently, suitable for some purposes; whilst others are extremely soft, and equally suitable for other uses, (74, 75, 78.)

17th. The breaking strain and contraction of area of *puddled*-steel plates, as in iron plates, are greater in the direction in which they are rolled; whereas in *cast*-steel they are less, (74, 75.)

18th. Iron, when fractured suddenly, presents invariably a crystalline appearance; when fractured slowly, its appearance is invariably fibrous, (119, 130—133.)

19th. The appearance may be changed from fibrous to crystalline by merely altering the shape of specimen so as to render it more liable to snap, (122, 134.)

20th. The appearance may be changed by varying the treatment so as to render the iron harder and more liable to snap, (123, 164, 165.)

21st. The appearance may be changed by applying the strain so suddenly as to render the specimen more liable to snap, from having less time to stretch, (124.)

22nd. Iron is less liable to snap the more it is worked and rolled, (125.)

23rd. The "skin" or outer part of the iron is somewhat harder than the inner part, as shown by appearance of fracture in rough and turned bars, (126, 58.)

24th. The mixed character of the scrap-iron used in large forgings is proved by the singularly varied appearance of the fractures of specimens cut out of crank-shafts, (67, 127, 135.)

25th. The texture of various kinds of wrought-iron is beautifully developed by immersion in dilute hydrochloric acid, which, acting on the surrounding impurities, exposes the metallic portion alone for examination, (135.)

26th. In the fibrous fractures the threads are drawn out, and are viewed externally, whilst in the crystalline fractures the threads are snapped across in clusters, and are viewed internally or sectionally. In the latter cases the fracture of the specimen is always at right angles to the length; in the former it is more or less irregular, (136.)

27th. Steel invariably presents, when fractured slowly, a silky fibrous appearance; when fractured suddenly, the appearance is invariably granular, in which case also the fracture is always at right angles to the length; when the fracture is fibrous, the angle diverges always more or less from 90°, (139.)

28th. The granular appearance presented by steel suddenly fractured is nearly free of lustre, and unlike the brilliant crystalline appearance of iron suddenly fractured; the two combined in the same specimen are shown in iron bolts partly converted into steel, (140.)

29th. Steel which previously broke with a silky fibrous appearance is changed into granular by being hardened, (141.)

30th. The little additional time required in testing those specimens whose rate of elongation was noted had no injurious effect in lessening the amount of breaking strain, as imagined by some, (143.)

31st. The rate of elongation varies not only extremely in different qualities, but also to a considerable extent in specimens of the same brand, (145, 146.)

32nd. The specimens were generally found to stretch equally throughout their length until close upon rupture, when they more or less suddenly drew out, usually at one part only, sometimes at two, and, in a few exceptional cases, at three different places, (147—149.)

33rd. The ratio of ultimate elongation may be greater in short than in long bars in some descriptions of iron, whilst in others the ratio is not affected by difference in the length, (159.)

34th. The lateral dimensions of specimens forms an important element in comparing either the rate of, or the ultimate, elongations—a circumstance which has been hitherto overlooked, (160.)

35th. Steel is reduced in strength by being hardened in water, while the strength is vastly increased by being hardened in oil, (161, 162, 164.)

36th. The higher steel is heated (without of course running the risk of being burned) the greater is the increase of strength, by being plunged into oil, (161, 162.)

37th. In a highly converted or hard steel the increase in strength and in hardness is greater than in a less converted or soft steel, (161, 162).

38th. Heated steel, by being plunged into oil instead of water, is not only considerably *hardened*, but *toughened* by the treatment, (162.)

39th. Steel plates hardened in oil and joined together with rivets are fully equal in strength to an unjointed soft plate, or the loss of strength by rivetting is more than counterbalanced by the increase in strength by hardening in oil, (163.)

40th. Steel rivets fully larger in diameter than those used in rivetting iron plates of the same thickness being found to be greatly too small for rivetting steel plates, the probability is suggested that the proper proportion for iron rivets is not, as generally assumed, a diameter equal to the thickness of the two plates to be joined, (163.)

41st. The shearing strain of steel rivets is found to be about a fourth less than the tensile strain, (163.)

42nd. Iron bolts, case-hardened, bore a less breaking strain than when wholly iron, owing to the superior tenacity of the small proportion of steel being more than counterbalanced by the greater ductility of the remaining portion of iron, (164, 123.)

43rd. Iron highly heated and suddenly cooled in water is hardened, and the breaking strain, when gradually applied, increased, but at the same time it is rendered more liable to snap, (165, 128, 123.)

44th. Iron, like steel, is softened, and the breaking strain reduced, by being heated and allowed to cool slowly, (167.)

45th. Iron subjected to the cold-rolling process has its breaking strain greatly increased by being made extremely hard, and not by being "consolidated," as previously supposed, (168, 176, 123.)

46th. Specimens cut out of crank-shaft are improved by additional hammering, (166, 128.)

47th. The galvanizing or tinning of iron plates produces no sensible effects on plates of the thickness experimented on. The results, however, may be different should the plates be extremely thin, (169.)

48th. The breaking strain is materially affected by the shape of the specimen. Thus the amount borne was much less when the diameter was uniform for some inches of the length than when confined to a small portion—a peculiarity previously unascertained and not even suspected, (170—172.)

49th. It is necessary to know correctly the exact conditions under which any tests are made, before we can equitably compare results obtained from different quarters, (172.)

50th. The startling discrepancy between experiments made at the Royal Arsenal, and by the writer, is due to the difference in the shape of the respective specimens, and not to the difference in the two testing machines, (173.)

51st. In screwed bolts the breaking strain is found to be greater when old dies are used in their formation than when the dies are new, owing to the iron becoming harder by the greater pressure required in forming the screw thread when the dies are old and blunt, than when new and sharp, (176, 168, 123.)

52nd. The strength of screw-bolts is found to be in proportion to their relative areas, there being only a slight difference in favour of the smaller compared with the larger sizes, instead of the very material difference previously imagined, (177, 174.)

53rd. Screwed bolts are not necessarily injured although strained nearly to their breaking point, (179.)

54th. A great variation exists in the strength of iron bars which have been cut and welded; whilst some bear almost as much as the uncut bar, the strength of others is reduced fully a third, (180.)

55th. The welding of steel bars, owing to their being so easily burned by slightly over heating, is a difficult and uncertain operation, (181, 15.)

56th. Iron is injured by being brought to a white or welding heat if not at the same time hammered or rolled, (182.)

57th. The breaking strain is considerably less when the strain is applied suddenly instead of gradually, though some have imagined that the reverse is the case, (185, 186.)

58th. The contraction of area is also less when the strain is suddenly applied, (187, 188.)

59th. The breaking strain is reduced when the iron is frozen; with the strain gradually applied, the difference between a frozen and unfrozen bolt is lessened, as the iron is warmed by the drawing out of the specimen, (189.)

60th. The amount of heat developed is considerable when the specimen is suddenly stretched, as shown in the formation of vapour from the melting of the layer of ice on one of the specimens, and also by the surface of others assuming tints of various shades of blue and orange, not only in steel, but also, although in a less marked degree, in iron, (189, 124.)

61st. The specific gravity is found generally to indicate pretty correctly the quality of specimens, (191.)

62nd. The density of iron is *decreased* by the process of wire-drawing, and by the similar process of cold-rolling, instead of *increased*, as previously imagined, (192, 193.)

63rd. The density in some descriptions of iron is also decreased by additional hot-rolling in the ordinary way; in others the density is very slightly increased, (195.)

64th. The density of iron is decreased by being drawn out under a tensile strain, instead of increased as believed by some, (194.)

65th. The most highly converted steel does not, as some may suppose, possess the greatest density, (196.)

66th. In cast-steel the density is much greater than in puddled-steel, which is even less than in some of the superior descriptions of wrought-iron, (196.)

198. The breaking strain per square inch of wrought-iron is generally stated to be about twenty-five tons for bars and twenty tons for plates. This corresponds very nearly with the results of the writer's experiments, of which the following table presents a condensed summary:—

		Lbs.		Lbs.		Lbs.	Tons
188 Bars, rolled,................	highest,	68,848	lowest,	44,584	mean,	57,555	= 25¼
72 Angle-iron, &c.,......... ..	do.	63,715	do.	37,909	do.	54,729	= 24½
167 Plates, lengthways,......	do.	62,544	do.	37,474	do.	50,787	= 21¼
160 Plates, crossways,........	do.	60,756	do.	32,450	do.	46,171	

199. Although the *breaking* strain is generally assumed to be about 25 tons for bars and 20 tons for plates, very great difference of opinion exists as to the amount of *working* strain, or the load which can with safety be applied in actual practice. The latter is variously stated at from a third to a tenth (see Appendix, A, G, H). It will be observed that whilst much discussion has arisen as to the amount of working strain, or the ratio the load should bear to that of the breaking strain, the important circumstance of the *quality* of the iron, as influencing the working strain, has been overlooked. The Board of Trade limits the strain to 5 tons, or 11,200 lbs. per square inch.

200. It must be abundantly evident, from the facts which have been produced, that the breaking strain, when taken alone, gives a false impression of, instead of indicating, the real quality of the iron, as the experiments which have been instituted reveal the somewhat startling fact, that frequently the inferior kinds of iron actually yield a higher result than the superior. The reason of this difference was shown to be due to the fact, that whilst the one quality retained its original area, only very slightly decreased by the strain, the other was reduced to less than one-half. Now, surely this variation, hitherto unaccountably completely overlooked, is of importance as indicating the relative hardness or softness of the material, and thus, it is submitted, forms an essential element in considering the safe load that can be practically applied in various structures. It must be borne in mind that although the softness of the material has the effect of lessening the amount of the *breaking* strain, it has the very opposite effect as regards the *working* strain. This holds good for two reasons: first, the softer the iron the less liable it is to snap; and second, fine or soft iron, being more uniform in quality, can be more depended upon in practice. Hence the load which this description of iron can suspend with safety may approach much more nearly the limit of its breaking strain than can be attempted with the harder or coarser sorts, where a greater margin must necessarily be left.

201. Special attention is now solicited to the practical use that may be made of the new mode of comparison introduced by the writer, viz.: the *breaking strain per square inch of the* FRACTURED *area of the specimen, instead of the breaking strain per square inch of the* ORIGINAL

area The two modes of comparison may be judged of by turning to Tables G, J, K, of which column 3, or 3 and 4, contain the results per original area; and column 6, or 6 and 7, per fractured area. They are also shown in the Diagram Plates VII.—X. In these tables and plates the various specimens follow each other according to their ascertained quality or breaking strain per fractured area.

202. As a necessary corollary to what he has just endeavoured to establish, the writer now submits, in addition, that the *working* strain should be in proportion to the breaking strain per square inch of fractured area, and not to the breaking strain per square inch of original area, as heretofore. He does not presume to say what that ratio should be, but he fully maintains that some kinds of iron experimented on by him will sustain with safety more than double the load that others can suspend, especially in circumstances where the load is unsteady, and the structure exposed to concussions, as in a ship, or to vibratory action as in a railway bridge.

203. In the Appendix is given a series of extracts, chiefly from *The Engineer* and other journals, having reference to the questions discussed in the present work. Some of the statements are so startling that the writer would almost have been afraid to have advanced them himself. They are, however, but too true, and it seems utterly unaccountable that upon a subject fraught with such momentous consequences, so few experiments should have been made, and so much vagueness and uncertainty allowed for so many years to exist, as some of these quotations evince.

204. In one of these extracts (Appendix D), on the subject of the strength of iron ships, it is remarked, in connection with certain experiments made by Lloyd's Committee, "Whilst Lloyd's experiments were made on plates only ⅜ inch thick, it is necessary, in order to procure a 12 years' classification of a 3,000 ton ship, to use iron $1\frac{1}{16}$ inch thick in the garboard streaks; and yet experiments have been made which appear to show that a rivetted joint, of even ½-inch iron, is absolutely *weaker* than one in ⅜-inch plate." The experiments are published in full detail in the *Transactions of the Institution of Naval Architects* (vol. i., 1860). The writer cannot find words to express his astonishment that so celebrated a body as Lloyd's should for one moment rest content with conclusions drawn from only *twenty-five* experiments. The plates experimented on were all of one thickness, viz., ⅜ inch, of one quality, and of an inferior description of iron, but the system of rivetting varied. These experiments are valuable so far as they go; but they should only be considered as preliminary to an

extended series worthy of emanating from so high a quarter. Such a series of experiments, which it is to be hoped may still be instituted, should embrace the various descriptions of iron and steel plates from the highest to the lowest qualities, as well as various modes of rivetting, size and form of rivets, and to ascertain the relative strength of plates according to their thickness. Data would thus be obtained of great practical value. The necessity of taking into consideration the *quality* of the plates experimented on, forms an important element in this question, as the writer believes that the diminution of strength produced by rivetting will be found to vary according to the quality of the metal, and not to be regulated by any definite ratio, as hitherto assumed. If this supposition prove true, an additional argument will be afforded for employing the finer descriptions of iron and steel in preference to the coarser sorts. It seems certain that experiments adequate to the importance of the subject must some day be made, and if so, why not at present ?*

205. The writer has not attempted to explain the cause of the mysterious change produced on steel by heating it and plunging it into water, or the no less singular result effected by plunging it, when heated, into oil, as was proved by his experiments given in Section XIII., 161-164, and also referred to in Appendix (M.) Neither has he tried to account for the mysterious change produced by subjecting iron to the processes of cold-rolling or wire-drawing. The explanation offered by some, of this difficult question, that the iron and steel are *condensed* by the processes to which they are subjected, is completely contradicted by fact, the metal being actually *expanded.* The aim of the writer being strictly to ascertain facts, and state the conclusions which he considers to be fairly deducible from them, he has not felt himself warranted in attempting to speculate on a subject respecting which so little is yet known.

206. In the Appendix (J) an extract is given from the continuation of the article in *The Practical Mechanic's Journal* on "The Annealing Temperatures of Metals, and Crystallization produced by Vibration," already referred to at page 60. Although the author of that paper ridicules keenly the idea of the structure of iron undergoing a change from fibrous to crystalline after being in use, as well as the various agencies to which the supposed effect is ascribed, he

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* Since the publication of the First Edition, the writer has been informed that Lloyd's Committee have ordered a very powerful machine to be constructed for testing anchors and chains, and that it is their intention to carry out an extensive series of experiments on rivetted joints.

does not point out the cause which led to this erroneous conclusion—a cause which it has been the anxious endeavour of the present writer to elucidate. He has sought to prove, by the results of actual experiments, that what had previously been imagined to indicate a real change in the structure of the metal is in reality only a change in the appearances presented by the fractures, and simply and entirely due to the act of breaking. The two different appearances, respectively designated by the terms, "a fibrous fracture" and "a crystalline fracture," are, he maintains, produced by the iron breaking gradually in the one case, and suddenly in the other. Hence, when the appearance presented was fibrous, it only proved that the piece had torn asunder; and when it was crystalline, that it had snapped.

207. The writer would suggest that his acid test should be adopted as an extremely simple, inexpensive, but at the same time efficient mode of judging comparatively of the various textures of iron. By immersing the specimens in dilute hydrochloric or muriatic acid (spirit of salt), the surrounding impurities were removed, exposing to view the metallic portion alone for examination. Thus the effect produced by repeated rolling was at once apparent, when we compared a highly worked or superior quality with a slightly worked or inferior. In the former the appearance presented by the bar was that of very fine and straight long hairs or threads lying closely together, as shown in specimens of Farnley and Bowling iron; in the latter, to some extent there was the same thread-like appearance, but indistinct and wavy, very irregular in size, in some parts lying close, in others far apart, as in bars of Dundyvan. Puddled-iron rolled, or wrought-iron in its lowest state, presented more of a woolly than a thread-like appearance, as in specimens of Scotch and Welsh puddled bars; the latter development seemed as if commencing to be formed by the first rolling, the former or woolly resemblance to be due to the puddling process. Swedish tilted bars presented, even to the naked eye, a beautiful, silvery, variegated appearance; also in Russian bar, the latter dense and very fine. Govan hammered bar had the same marked, fine, thread-like appearance, as in Farnley rolled bar; but the threads were not so straight and equal. The crank-shaft specimens were extremely varied, and had a wood-like appearance, some portions dense, others porous, with here and there a silvery-looking vein, distinctly different from the other portions; in some places the fibres or threads were seen sideways, in others endways. Specimens from the armour-plates were like the last, but rather more porous.

208. When the deplorable loss of the "Royal Charter" occurred

public attention was directed to the notorious fact that, till recently at least, any kind of iron was considered good enough for shipbuilding purposes. This state of matters was ably exposed in a letter signed "Amicus," which appeared in *The Times* a few days after the lamentable event, an extract from which, and also from a second letter by the same pen, are given in Appendix (B). That the employment of the very best material would be accompanied with even great pecuniary advantage is forcibly set forth by Mr. J. G. Lawrie in a paper "On Lloyd's Rules for Iron Ships and their Improvement," an extract from which is also given in Appendix (C). It is hoped that the experiments, the results of which are detailed in the accompanying Tables, may be useful in supplying the data which Mr. Lawrie has assumed in stating his argument. It may be observed on this subject, in passing, that a slight allowance will require to be made for the difference in the respective specific gravities of the finer and coarser materials.

209. In conclusion, the writer ventures only to express a hope that the experiments, on which he has been so long and unremittingly engaged, may not prove wholly unserviceable to practical science and the world at large. The importance of possessing a thorough knowledge of the capabilities and strength of substances on which the lives and property of so many human beings depend, is a proposition which no one will attempt to deny. The only excuse, if indeed excuse it can be called, for employing an inferior description of material in the rearing of structures on the stability of which such momentous issues are involved, is ignorance or misapprehension of its proper quality. The writer has endeavoured, by a plain statement of facts, to furnish some information on a subject which seems till now to have been denied the attention which its paramount importance demands. Were this question fairly taken up and considered, some security might be afforded against the repetition in future of disasters occasioned by its being so often practically ignored. The necessity of using nothing but the very best descriptions of metal where human life or valuable property is at stake may, he trusts, come soon to be more generally recognized than it is at present. And that an increased demand for the finer varieties may conduce to a generous emulation amongst the manufacturers to improve still further the quality of their productions. Should his labours tend in any, even the smallest, degree to diminish the annual sacrifice of life and property occasioned by faulty material and workmanship, he will feel the satisfaction that they have at least not been entirely in vain.

TABULATED RESULTS.

FIRST SERIES.

NOTE.—All the pieces were taken *promiscuously* from Engineers' o
***b* denotes bad fracture; *r*, s**

Index No.	District	Names of the Makers or Works.		Description	ORIGINAL Diameter.	ORIGINAL Area	Weight on Steelyd	Breaking Weight per square inch of Original Area.	
					1.	2.	3.	4.	5.
					inch	sq. in.	lbs.	lbs.	lbs.
1	Sheffield	T. TURTON & SONS, Cast Steel for Tools, (from Acadian iron.)		All forged from rolled bars by the same smith, reheated after hammering, and allowed to cool gradually	·53	·2207	822	145,383	132.909
2		" "			·55	·2376	908	145,177	
3		" "			·57	·2552	894	133,628	
4		" "			·59	·2734	965	132,004	
5		" "			·57	·2552	852	129,020	
6		" "			·56	·2462	663	112,242	
7		THOMAS JOWITT, Cast Steel for Tools.			·56	·2462	980	148,294	132.402
8		" "			·58	·2642	1008	141,159	
9		" "			·57	·2552	792	122,437	
10		" "			·57	·2552	749	117,719	
11		Do. Do. Cast Steel for Chisels.			·58	·2642	978	137,979	124.852
12		" "			·56	·2462	852	133,737	
13		" "			·58	·2642	908	130,568	
14		" "			·58	·2642	908	130,568	
15		" "			·58	·2642	821	121,340	
16		" "			·60	·2827	858	117,757	
17		" "			·57	·2552	720	114,537	
18		" "			·58	·2642	736	112,331	
19		Do. Do. Cast Steel for Drifts.			·57	·2552	865	130,447	115.882
20		" "			·57	·2552	865	130,447	
21		" "			·57	·2552	642	105,980	
22		" "			·57	·2552	557	96,653	
23		T. JOWITT, Double Shear Steel.			·56	·2462	778	125,321	118.468
24		" "			·57	·2552	793	122,547	
25		" "			·57	·2552	763	119,255	
26		" "			·57	·2552	649	106,747	
27		BESSEMER Sheffield.	Samples		·75	·4417	1619	123,165	111.460
28		" (Tool). "			·65	·3318	1077	118,221	
29		" "			·74	·4300	1420	113,588	
30		" "			·74	·4300	1390	111,005	
31		" "			·74	·4300	1347	108,805	
32		" "			·73	·4184	1276	107,070	
33		" "			·74	·4300	1304	106,004	
34		" "			·73	·4184	1219	103,255	
35		WILKINSON Ⓛ Blister Steel.			·57	·2552	735	116,183	104.293
36		" "			·58	·2642	735	112,226	
37		" "			·60	·2827	678	99,236	
38		" "			·58	·2642	521	89,546	
39		T. JOWITT, Cast Steel for Taps.			·57	·2552	685	110,697	101.151
40		" "			·59	·2734	713	106,196	
41		" "			·57	·2552	621	103,675	
42		" "			·57	·2552	442	84,036	
43		MOSS & GAMBLES, Cast Steel for Rivets.	Samples.	Rolled bars ¾ in. round.	·75	·4417	1518	116,763	107.286
44		" "			·75	·4417	1390	108,649	
45		" "			·75	·4417	1291	102,309	
46		" "			·75	·4417	1276	101,422	
47		NAYLOR, VICKERS, & CO., Cast Steel for Rivets.		Rolled bars ¾ in. round.	·75	·4417	1447	112,262	106.615
48		" "			·75	·4417	1419	110,486	
49		" "			·74	·4300	1247	102,293	
50		" "			·75	·4417	1276	101,421	

ept those marked *Samples*, which were received from the Makers.
acture; *s*, size at smallest part.

e between al and d Areas.		Breaking Wght per sq in of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght per sq in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.	
			Diameter	Area.									Gran	Kind.
9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	24.
. in	₱ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	₱ ct.	lbs.	inch	inch.	in.	₱ ct.	₱ ct.	
116	4·7	139.124	·52*s* ·53 ·55 ·58 ·55 ·56	·2124 ·2207 ·2376 ·2642 ·2376 2462	·0083 ·0169 ·0176 ·0092 ·0176 ·0000	·0116	4·7	139.124	·14 ·18 ·18 ·14 ·16 ·03	·14	2·6	5·4	100 100 100 100 100 100	A A A A A A
0132	5·1	139,616	·53 ·57 ·54*f* ·53*s* ·52*f* ·50*s*	·2207 ·2552 ·2290 ·2207 ·2124 ·1963	·0255 ·0090 ·0262 ·0345 ·0428 ·0589	·0328	12·8	151.857	·15 ·08 ·12 ·20	·14	2·7	5·2	100 100 100 100	A A C C
·0210	8·0	135,497	·55 ·50 ·55 ·60*f* ·57*s* ·55 ·53 ·49 ·52*f* ·48*s*	·2376 ·1963 ·2376 ·2552 ·2376 ·2207 ·1885 ·2124 ·1809	·0266 ·0499 ·0266 ·0090 ·0266 ·0620 ·0667 ·0518 ·0833	0447	17·0	150.243	·15 ·14 ·11 ·12 ·18 ·16 ·32 ·16	·17	2·4	7·1	100 100 100 100 100 100 100 100	A A A C A A A C
·0366	14·3	135.283	·50 ·53 ·50 ·49	·1963 ·2207 ·1963 ·1885	·0589 ·0345 ·0589 ·0667	·0548	21·5	147.570	·30 ·25 ·35 ·38	·32	2·4	13 3	100 100 100 10	A A A I
·0196	7·8	128,380	·52 ·52 ·54 ·45	·2124 ·2124 ·2290 ·1590	·0338 ·0428 ·0262 ·0962	·0497	19·6	147,393	·38 ·30 ·28 ·35	·35	2·6	13·5	100 100 100 90	A A A A I
·0198	4·8	116,933	·72*s* ·64*s* ·59 ·65 ·65 ·72 ·62 ·52	·4071 ·3216 ·2734 .3318 ·3318 ·4071 ·3019 ·2124	·0346 ·0102 ·1566 ·0982 ·0982 ·0113 ·1281 ·2060	0929	22·3	143,327	·40 ·16 ·53 ·42 ·47 ·12 ·35 ·48	·37	6·8	5·5	100*r* 100 90 90 100 100 90 50	B C B C B I F B B F B I
·0223	8·4	113,649	·55 ·53 ·53 ·45	·2376 ·2207 ·2207 ·1590	·0176 ·0435 ·0620 ·1052	·0571	21·4	132,472	·27 ·25 ·24 ·40	·29	3·0	9·7	100*r* 100*r* 100*r* 90*r*	A A A A I
·0243	9·4	111,712	·48 ·47 ·47 ·52	·1809 ·1735 ·1735 ·2124	·0743 ·0999 ·0817 ·0428	0747	28·8	142,070	·24 ·30 ·26 ·30	·28	2·6	10·8	100 100 90 85	A A A I D
·0402	9·1	118,057	·65 ·63 ·60 ·59	·3318 ·3116 ·2827 ·2734	·1099 ·1301 ·1590 ·1683	·1418	32·1	158,013	·80 ·85 ·85 ·88	·84	6·8	12·4	90 76 50 0	F F F I I
·0401	9·1	117,359	·60 ·61 ·62 ·62	·2827 ·2922 ·3019 ·3019	·1590 ·1495 ·1281 ·1398	·1441	32·8	158,785	·55 ·56 ·48 ·50	·52	6·0	8·7	85 90 95 90	F I F I F F

TAB

NOTE.—All the pieces were taken *promiscuously* from Engineers'
***b* denotes bad fracture; *r*,**

Index No.	District.	Names of the Makers or Works.	Description	ORIGINAL Diameter.	ORIGINAL Area	Weight on Steelyd.	Breaking Weight per square inch of Original Area.	
				1.	2.	3.	4.	5.
				inch	sq. in.	lbs.	lbs.	lbs.
51	Prussia.	KRUPP, Dusseldorf, Cast Steel for Bolts.	Rolled bars, round.	·92	·6650	1961	96,208	**92,015**
52		〃 〃		·93	·6808	1982	94,838	
53		〃 〃		·91	·6504	1789	90,962	
54		〃 〃		·91	·6504	1675	86,054	
55	Sheffield	SHORTRIDGE, HOWELL, & Co. Homogeneous Metal,	Rolled bars $^9/_{16}$ in. for rivets.	·55	·2376	521	99,570	**90,647**
56		〃 〃		·57	·2552	536	94,349	
57		〃 〃		·57	·2552	464	86,450	
58		〃 〃		·56	·2462	399	82,218	
59		Do. Do.	Forged.	·77	·4657	1252	94,752	**89,724**
60		〃 〃	〃	·75	·4418	1098	90,118	
61		〃 〃	〃	·75	·4418	1084	89,230	
62		〃 〃	〃	·75	·4418	1014	84,794	
63		T. JOWITT, Spring Steel.	Forged from ¾ in. rolled bars.	·55	·2376	378	82,719	**72,529**
64		〃 〃		·57	·2552	341	72,955	
65		〃 〃		·55	·2376	264	69,284	
66		〃 〃		·56	·2462	249	65,158	
69	Liverpool.	MERSEY Co., Puddled Steel.	Forged.	·75	·4417	864	75,304	**71,486**
70		〃 〃	〃	·76	·4536	888	74,810	
71		〃 〃	〃	·77	·4717	866	70,634	
72		〃 〃	〃	·75	·4417	790	70,613	
73		〃 〃	〃	·76	·4536	818	70,489	
74		〃 〃	〃	·74	·4300	706	67,065	
75	Glasgow	BLOCHAIRN Puddled Steel.	Rolled bars.	·75	·4417	861	75,114	**70,166**
76		〃 〃		·75	·4417	833	73,339	
77		〃 〃	〃	·62 × ·60	·3720	647	73,080	
78		〃 〃	〃	·75	·4417	826	72,895	
79		〃 〃	〃	·75	·4417	805	71,564	
80		〃 〃	〃	1·00	·7854	1219	55,006	
81		Do. Do.	Forged from slabs.	·75	·4417	804	71,501	**65,255**
82		〃 〃		·75	·4417	804	71,501	
83		〃 〃	〃	·75	·4417	783	70,169	
84		〃 〃	〃	·76	·4536	790	68,761	
85		〃 〃	〃	·76	·4536	762	67,032	
86		〃 〃	〃	·77	·4657	384	42,564	
87		Do. Do.	Forged from rolled bars.	·77	·4657	846	70,341	**62,769**
88		〃 〃		·77	·4657	832	69,500	
89		〃 〃		·76	·4536	734	65,304	
90		〃 〃		·77	·4657	440	45,931	

EL BARS—(*Continued.*)

ept those marked *Samples*, which were received from the Makers.
acture; *s*, size at smallest part.

between d and 1 Areas.		Breaking Wght per sq. in. of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght per sq in. of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.	
			Diameter	Area.									Gran	Kind.
.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	24.
in.	℔ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	℔ ct.	lbs.	inch.	inch.	in.	℔ ct.	℔ ct.	
64	13·1	105,910	·71 ·75 ·88*s* ·62	·3958 ·4417 ·6082 ·3019	2692 ·2391 ·0422 3485	·2247	34·0	139,434	1·14 1·37 0·57 1·30	1·10	7·2	15·3	10 85 100 0*r*	F I F C I
320	12·9	104,017	·46 ·46 ·45 ·42	·1662 ·1662 ·1590 ·1385	·0714 ·0890 ·0962 ·1077	·0911	36·6	142,920	·38 ·50 ·57 ·76	·55	4·0	13·7	65 0 55 0	F I I F I I
545	12·2	102,329	·58 ·61 ·68 ·72*s*	·2642 ·2922 ·3632 ·4071	2015 ·1496 ·0786 ·0347	·1161	26.0	121,212	·70 ·87 ·63 ·30	·62	5·2	11·9	80 90 100*r* 100	F I F I A C
396	16·2	86,523	·52 ·45 ·50 ·47	·2124 ·1590 ·1963 ·1735	·0252 ·0962 ·0413 ·0727	·0588	24·1	95,490	·20 ·77 ·32 ·51	·45	2·5	18·0	80 0*r* 0 0*r*	D E E E
819	18·2	87,451	·64 ·68 ·61 ·57 ·59 ·55	·3216 ·3632 ·2922 ·2552 ·2734 ·2376	·1201 ·0904 ·1795 ·1865 ·1802 ·1924	·1582	35·3	110,451	·85 ·56 ·90 ·94 ·92 ·88	0·84	4·4	19·1	0*r* 34*rr* 0*rr* 0 0*r* 0*r*	H G H H I H H
532	10·9	76,699	·70 ·62 ·52 ·71 ·61 ·95	·3848 ·3019 ·2704 ·3958 ·2922 ·7088	·0569 ·1398 ·1016 ·0459 ·1495 ·0766	·0950	19·4	84,871	·40 ·87 ·49 ·45 ·75 ·24	0·53	4·7	11·3	65 18 0 0 0 3*br*	F G H H H G
476	10 5	72,775	·68 ·68 ·64 ·66 ·67 ·75	·3632 ·3632 ·3216 ·3421 ·3526 ·4417	·0785 ·0785 ·1201 ·1115 ·1010 ·0240	·0856	19·0	80,370	·61 ·46 ·78 ·63 ·57 ·12	0·53	4·4	12·0	0*r* 0 0 0*r* 0*rr* 0*br*	H G G H G H G
295	6·4	67,022	·73 ·72 ·68 ·75	·4184 ·4071 ·3632 ·4417	·0473 ·0586 ·0904 ·0240	·0551	11·9	71,231	·62 ·42 ·40 ·14	0·40	4·4	9·1	0 0*r* 50*r* 0*br*	G H G H G G

Note.—All the pieces were taken *promiscuously* from Engineers'
b denotes bad fracture; r,

Index No	District.	Names of the Makers or Works.	Description	ORIGINAL Diameter.	ORIGINAL Area	Weight on Steelyd	Breaking Weight per square inch of Original Area	
				1. inch	2. sq. in.	3. lbs.	4. lbs.	5. lbs.
101	Yorkshire	Low-Moor.	Rolled bars 1 inch square.	1·03 × 1·01	1·0403	1990	62,298	60,364
102		" "		1·02 × 1·01	1·0302	1904	60,565	
103		" "		1·03 × 1·01	1·0403	1882	59,390	
104		" "		1·03 × 1·01	1·0403	1875	59,202	
105		Do. Do.	Rolled bars 1 inch round.	1·00	·7854	1504	65,166	61,798
106		" "		"	"	1433	62,635	
107		" "		"	"	1361	60,069	
108		" "		"	"	1340	59,320	
109		Do. Do.	Rolled bars $^{11}/_{16}$ in. for rivets.	·69	·3712	504	62,451	60,075
110		" "		"	"	483	60,867	
111		" "		"	"	455	58,756	
112		" "		"	"	448	58,228	
113		Do. Do.	Planed from 1 in. sq. bars.	·78 × ·78	·6084	1019	61,805	60,245
114		" "		·77 × ·77	·5929	947	60,020	
115		" "		·77 × ·77	·5929	947	60,020	
116		" "		·78 × ·78	·6084	961	59,135	
117		Do. Do.	Forged from 1½ in. round bars	·77	·4657	805	67,876	66,392
118		" "		·78	·4779	823	67,198	
119		" "		·80	·5026	854	65,622	
120		" "		·77	·4657	755	64,871	
121		Bowling.	Rolled bars 1 in. round.	1·00	·7854	1519	65,701	62,404
122		" "		"	"	1461	63,634	
123		" "		"	"	1404	61,602	
124		" "		"	"	1322	58,678	
125		Do. Do.	Turned from 1½ in. round bars	1·00	·7854	1440	62,885	61,477
126		" "		"	"	1433	62,635	
127		" "		"	"	1382	60,817	
128		" "		"	"	1347	59,570	
129		Farnley.	Rolled bars 1 in. round.	1·00	·7854	1475	64,133	62,886
130		" "		"	"	1475	64,133	
131		" "		"	"	1461	63,634	
132		" "		"	"	1349	59,642	
133	Staffordshire.	J. Bradley & Co. Ⓛ (Charcoal.) — Samples	Rolled bars 1 in. round.	1·00	·7854	1304	58,036	57,216
134		" "		"	"	1297	57,787	
135		" "		"	"	1276	57,039	
136		" "		"	"	1247	56,004	
137		Do. B. B. Scrap.	Rolled bars 1 in. round.	1·00	·7854	1359	59,998	59,370
138		" "		"	"	1347	59,570	
139		" "		"	"	1340	59,320	
140		" "		"	"	1319	58,571	
141		Do. SC ♛	Rolled bars ¾ in. for rivets.	·75	·4417	601	58,632	56,715
142		" "		"	"	594	58,190	
143		" "		"	"	551	55,463	
144		" "		"	"	537	54,575	
145		Do. Do.	Rolled bars ⅞ in. round.	·89	·6220	1089	63,604	62,231
146		" "		"	"	1061	62,344	
147		" "		"	"	1047	61,714	
148		" "		"	"	1037	61,263	
149		G. B. Thornycroft & Co. TNS.	Rolled bars $^{13}/_{16}$ in. for rivets.	·81	·5153	790	60,528	59,278
150		" "		"	"	776	59,767	
151		" "		"	"	769	59,387	
152		" "		"	"	733	57,431	
153		Lord Ward, L ♛ W.R-O.	Rolled bars $^{11}/_{16}$ in. for rivets.	·70	·3848	547	63,373	59,753
154		" "		"	"	504	60,244	
155		" "		"	"	476	58,207	
156		" "		"	"	462	57,188	

N BARS.

cept those marked *Samples*, which were received from the Makers.
racture; *s*, size at smallest part.

e between nal and ed Areas.		Breaking Wght. per sq. in. of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght. per sq in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
			Diameter	Area.									Crys.	Col.	Kind
9. ·in.	10. ℔ ct.	11. lbs.	12. inch.	13. sq. in.	14. sq. in.	15. sq. in	16. ℔ ct.	17. lbs.	18. inch.	19. inch.	20. in.	21. ℔ ct.	22. ℔ct.	23.	24.
444	13·9	70,131	·69 × ·69 ·80 × ·80 ·71 × ·71 ·72 × 72	·4761 ·6400 ·5041 ·5184	·5639 ·3900 ·5359 ·5216	·5028	48·5	117,147	2·31 1·80 1·80 1·65	1·89	7·6	24·9	0 0 *r* 4 0	Bright lightish-grey; fibre, compact and fine	N N N N
1492	19·0	76,290	·68 ·70 ·68 ·68	·3632 ·3848 ·3632 ·3632	·4222 ·4006 ·4222 ·4222	·4168	53·1	131,676	1·90 1·86 1·94 1·92	1·91	7·2	26·5	0 0 0 0		P P P P
644	17·3	72·685	·48 ·46 ·49 ·47	·1809 ·1662 ·1885 ·1735	·1903 ·2050 ·1827 ·1977	·1939	52·2	125,775	1·31 1·35 1·34 1·40	1·35	6·6	20·5	0 0 0 0		P P P P
749	12·5	68,840	·65 × ·65 53 × ·53 ·53 × ·53 ·53 × ·53	·4225 ·2809 ·2809 2809	·1859 ·3120 ·3120 ·3275	·2843	47·3	114,410	1·60 1·52 1·80 1·83	1·69	7·1	23·8	0 0 0 0		O O O O
680	14·2	77·383	·61 ·60 ·58 ·58	·2922 ·2827 ·2642 ·2642	·1735 ·1952 ·2384 ·2015	·2022	42·3	115,040	1·12 1·13 1·23 0·97	1·11	5 5	20·2	0 0 0 0		P P P P
1276	16·2	74,487	·80 ·74 ·75 ·66	·5026 ·4300 ·4417 ·3421	·2828 ·3554 ·3437 ·4433	·3563	45·3	114,220	1·53 1·80 1·80 1·90	1·76	7·2	24·4	0 *r* 0 *r* 0 0		P P P P
1312	16·7	73,863	·73 ·73 ·70 ·70	·4184 ·4184 ·3848 ·3848	3670 ·3670 ·4006 ·4006	·3838	48·8	120,229	1·68 1·88 1·90 1·50	1·74	6·7	26·0	0 0 0 0		P P P P
1456	18·5	77,200	·70 ·72 ·69 ·70	·3848 ·4071 ·3739 ·3848	·4006 ·3783 ·4115 ·4006	·3977	50·6	127,425	1·80 1·60 2·00 1·56	1·74	6·8	25·6	0 0 *r* 0 0		P P P P
1668	21·2	72,700	·62 ·63 ·62 ·63	·3019 ·3116 ·3019 ·3116	·4835 ·4738 ·4835 ·4738	·4787	60·9	146,521	2·00 2·00 1·86 1·86	1·93	6·4	30·2	0 *r* 0 *r* 0 *r* 0 *r*	Bright grey; fibre, very fine.	L L L L
1563	19·9	74,378	·70 ·69 ·69 ·69	·3848 ·3739 ·3739 ·3739	·4006 ·4115 ·4115 ·4115	·4088	52·0	123,805	2·00 2·06 2·11 1·90	2·02	7·6	26·6	0 *r* 0 *r* 0 *r* 0 *r*		M M M M
864	19·5	70,503	·55 ·53 ·55 ·50	·2376 ·2207 ·2376 ·1963	·2041 ·2210 ·2041 ·2454	·2186	49·5	112,336	1·75 1·34 1·42 1·60	1·53	6·8	22·5	0 0 0 0	Dullish-grey; fibre, compact	Q Q Q Q
1067	17·2	75,133	·70 ·66 ·82 ·65	·3848 ·3421 ·5281 ·3318	·2372 ·2799 ·0939 ·2902	·2253	36·2	97,575	1·80 1·85 1·16 1·68	1·62	7·3	22·2	0 *r* 0 60 0		Q Q X Q
882	17·1	71,540	·62 ·63 ·62 ·63	·3019 ·3116 ·3019 ·3116	·2134 ·2037 ·2134 ·2037	·2085	40·4	99,595	1·83 1·50 1·78 1·54	1·66	7·4	22·4	0 0 *r* 0 0		T T T T
031	16·4	71,621	·55 ·52 ·55 ·59	·2376 ·2124 ·2376 ·2734	·1472 ·1724 ·1472 ·1114	·1446	37·6	95,724	1·32 1·38 1·16 0·92	1·19	6·4	18·6	0 *r* 3 0 2 *b*		T T T T

TABL

Note.—All the pieces were taken *promiscuously* from Engineers' or
b denotes bad fracture; *r*, sli

Index No.	District.	Names of the Makers or Works.	Description	ORIGINAL Diameter.	ORIGINAL Area	Weight on Steelyd.	Breaking Weight per square inch of Original Area		STI Diam
				1. inch	2. sq. in.	3. lbs.	4. lbs.	5. lbs.	6 inc
157	Lanarkshire	Govan Ex. B. Best.	Rolled bars ¾ in. square.	·77 × ·77	·5929	890	57,328	56,655	·72 ×
158		" "		"	"	890	57,328		·72 ×
159		" "		"	"	876	56,667		·72 ×
160		" "		"	"	847	55,297		·72 ×
161		Do. Do.	Rolled bars ¾ in. round.	·76	·4536	633	59,070	57,591	·7
162		" "		·76	·4536	623	58,452		·7
163		" "		·70	·3848	462	57,190		·6
164		" "		·75	·4417	554	55,653		·7
165		Govan, Ex. B. Best.	Rolled bars 1⅛ in. round.	1·15	1·0387	1875	59,276	58,358	1·0
166		" "		1·16	1·0568	1890	58,658		1·0
167		" "		1·15	1·0387	1833	58,135		1·0
168		" "		1·15	1·0387	1804	57,362		1·0
169		Do. Do.	Rolled bars 1 in. round.	1·02	·8171	1419	59,726	59,109	·9
170		" "		"	"	1419	59,726		·9
171		" "		"	"	1390	58,732		·9
172		" "		"	"	1376	58,252		·9
173		Do. Do.	Rolled bars ⅞ in. round.	·90	·6362	1019	59,104	58,169	·8
174		" "		"	"	1012	58,796		·8
175		" "		"	"	998	58,180		·8
176		" "		"	"	962	56,595		·8
177		Do. Do.	Rolled bars ¾ in. round.	·77	·4657	671	59,820	57,400	·7
178		" "		"	"	671	59,820		·7
179		" "		"	"	619	56,694		·7
180		" "		"	"	562	53,266		·7
181		Govan B. Best.	Rolled bars 1⅛ in. round.	1·13	1.0029	1989	64,575	60,879	1·0
182		" "		1·12	0·9852	1875	62,495		1·0
183		" "		1·13	1·0029	1904	62,201		1·0
184		" "		1·13	1·0029	1619	54,245		1·1
185		Do. Do.	Rolled bars 1 in. round.	1·01	·8012	1575	66,363	62,849	·9
186		" "		1·01	·8012	1533	64,895		·9
187		" "		1·00	·7854	1361	60,069		·9
188		" "		1·00	·7854	1361	60,069		·97
189		Do. Do.	Rolled bars ⅞ in. round.	·90	·6362	1090	62,229	61,341	·82
190		" "		·90	·6362	1090	62,229		·8
191		" "		·89	·6220	1019	60,453		·81
192		" "		·89	·6220	1019	60,453		·82
193		Do Do.	Rolled bars ¾ in. round.	·77	·4657	783	66,553	64,795	·71
194		" "		"	"	780	66,373		·72
195		" "		"	"	747	64,390		·71
196		" "		"	"	705	61,864		·74
197		Govan *	Rolled bars 1⅛ in. round.	1·15	1·0387	1961	61,594	58.326	1·05
198		" "		"	"	1933	60,840		1·07
199		" "		"	"	1847	58,521		1·07
200		" "		"	"	1618	52,348		1·10
201		Do. Do.	Rolled bars 1 in. round.	1·04	·8498	1519	60,722	59,424	·98
202		" "		1·02	·8171	1426	59,965		·95
203		" "		1·04	·8498	1475	59,272		·95
204		" "		1·02	·8171	1361	57,738		·97
205		Do. Do.	Rolled bars ⅞ in. round.	·90	·6362	1190	66,630	63.956	·84
206		" "		"	"	1119	63.505		·82
207		" "		"	"	1104	62,845		·84
208		" "		"	"	1104	62,845		·85
209		Do. Do.	Rolled bars ¾ in. round.	·77	·4657	733	63,547	61.887	·70
210		" "		"	"	719	62,705		·71
211		" "		"	"	704	61,804		·69
212		" "		"	"	662	59,493		·72

B A R S—(*Continued*).

those marked *Samples*, which were received from the Makers.

re; *s*, size at smallest part.

ween d eas.	Breaking Wght. per sq. in. of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght. per sq. in. of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
		Diameter.	Area.									Crys	Col	Kind
10. ℔ ct.	11. lbs.	12. inch.	13. sq. in.	14. sq. in.	15. sq. in.	16. ℔ ct.	17. lbs.	18. inch.	19. inch.	20. in.	21. ℔ ct.	22. ℔ ct.	23.	24.
12·6	64,797	·58 × ·58 ·59 × .59 ·58 × ·58 ·58 × ·58	·3364 ·3481 ·3364 ·3364	·2565 ·2448 ·2565 ·2565	·2536	42·7	99,000	1·52 1·56 1·50 1·64	1·55	8·1	19·1	0 0 0 0	Brightish-grey; fibre close and uniform throughout the series.	R R R R
13·0	66,242	·58 ·58 ·55 ·60	·2642 ·2642 ·2376 ·2827	·1894 ·1894 ·1472 ·1590	·1712	39·5	95,248	1·82 1·70 1·06 1·10	1·42	8·2	17·3	0 0 0 0		S S S S
17·4	70,645	·90 ·86 ·90 ·90	·6362 ·5812 ·6362 ·6362	·4025 ·4756 ·4025 ·4025	4208	40·3	97,821	1·66 1·78 1·66 1·56	1·67	7·0	23·8	0 0 0 0		S S S S
13·3	68,140	·78 ·79 ·79 ·80	·4779 ·4902 ·4902 ·5026	·3392 ·3269 ·3269 ·3145	·3269	40·0	98,527	1·70 1·40 1·38 1·32	1·45	6·5	22·3	0 0 0 0		S S S S
15·0	68,446	·66 ·68 ·69 ·69	·3421 ·3632 ·3739 ·3739	·2941 ·2730 ·2623 ·2623	·2729	42·9	101,863	1·16 1·20 1·16 1·08	1·15	6·0	19·2	0 0 0 0		S S S S
15·6	68,018	·60 ·64 ·59 ·59	·2827 ·3216 ·2734 ·2734	·1830 ·1441 ·1923 ·1923	·1779	38·0	92,880	1·12 0·90 1·02 0·82	0·97	5·5	17·6	0 3 0 0		S S S S
2·0	69,161	0·95 0·84 0·92 1·10	·7088 ·5441 ·6650 ·9503	·2941 ·4411 ·3379 ·0536	·2817	28·2	84,770	1·48 1·50 1·42 0·36	1·19	7·0	17·0	72 3*r* 3*r* 95	Greyish; fibre close, but irregular	U S S Y
13·7	73,111	·84 ·82 ·75 ·97*s*	·5441 ·5281 ·4417 ·7392	·2571 ·2731 ·3434 ·0462	·2297	28·9	88,550	1·42 1·37 1·60 0·58	1·24	6·5	19·1	5*r* 0 0 100		U S S Y
6·6	73,527	·68 ·72 ·67 ·78	·3632 ·4071 ·3526 ·4779	·2730 ·2291 ·2694 ·1441	·2289	36·4	96,442	1·26 1·14 1·41 1·00	1·20	6·0	20·0	0*r* 33*r* 0 20*r*		S U S U
2·5	74,246	·60 ·62 ·60 ·69	·2827 ·3019 ·2827 ·3739	·1830 ·1638 ·1830 ·0918	·1554	33·4	97,245	1·00 1·12 1·17 0·50	0·95	5·5	17·3	2 4 0 20		S S S V
3·0	67,046	0·93 1·03 1·00*s* 1·01	·6808 ·8333 ·7854 ·8012	·3579 ·2054 ·2583 ·2375	·2635	25·3	78,139	1·70 1·04 1·30 0·64	1·17	7·0	16·7	2 70 4*rr*	Loose and irregular	S V S U
2·6	68,106	·96 ·82 ·88 ·90	·7238 ·5281 ·6082 ·6362	·1260 ·2890 ·2416 ·1809	·2094	25·1	79,373	0·74 1·50 1·24 0·80	1·07	6·5	16·4	100 0 25*rr* 10		Y S V U
4·2	74,535	·77 ·68 ·77 ·84	·4657 ·3632 ·4657 ·5441	·1705 ·2730 ·1705 ·0921	·1765	27·7	88,512	1·00 1·35 1·07 0·80	1·05	6·0	15·8	28 1 10 100		V S U Y
6·1	73,869	·60 ·61 ·62 ·65	·2827 ·2922 ·3019 ·3318	·1830 ·1735 ·1638 ·1330	·1635	35·1	95,319	1·27 1·06 1·22 0·80	1·09	5·8	18·8	0 5 0 8*r*		S U S U

NOTE.—All the pieces were taken *promiscuously* from Engineers' or M
***b* denotes bad fracture; *r*, slig**

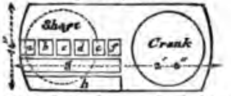
Index No.	District.	Names of the Makers or Works.	Description	ORIGINAL		Weight on Steelyd	Breaking Weight per square inch of Original Area.		STR
				Diameter.	Area				Diame
				1.	2.	3.	4.	5.	6.
				inch	sq. in.	lbs.	lbs.	lbs.	inch
213	Lanarkshire	GLASGOW B. BEST.	Rolled bars 1 inch round.	1·00	·7854	1382	60,817	58,885	·92
214		" "		1·00	·7854	1347	59,569		·91
215		" "		1·00	·7854	1347	59,569		·92
216		" "		0·98	·7543	1248	58,351		·90
217		" "		0·99	·7698	1219	56,121		·90
218		Do. Do.	Rolled bars $^{15}/_{16}$ in. round.	·92	·6650	1132	61,296	58,910	·86
219		" "		"	"	1132	61,296		·86
220		" "		"	"	1033	57,134		·86
221		" "		"	"	1004	55,913		·86
222		Do. BEST RIVET.	Rolled bars $^{7}/_{8}$ in. round.	·87	·5945	925	58,823	57,092	·81
223		" "		"	"	876	56,515		·80
224		" "		"	"	876	56,515		·80
225		" "		"	"	876	56,515		·80
226		Do. B. BEST.	Forged from 1 inch rolled bars.	·78	·4779	712	60,695	59,045	·72
227		" "		·77	·4657	683	60,541		·70
228		" "		·77	·4657	669	59,700		·71
229		" "		·72	·4071	519	57,976		·69
230		" "		·79	·4902	662	56,316		·75
231		GOVAN B. BEST.	Rolled bars $^{3}/_{4}$ in. round.	·76	·4536	666	61,106	59,548	·72
232		" "		·76	·4536	637	59,316		·70
233		" "		·76	·4536	630	58,884		·72
234		" "		·75	·4417	605	58,886		·71
235		COATBRIDGE BEST RIVET.	Rolled bars $^{3}/_{4}$ in. round.	·75	·4417	679	63,577	61,723	·70
236		" "		"	"	664	62,626		·70
237		" "		"	"	649	61 675		·69
238		" "		"	"	607	59,013		·71
239		BLOCHAIRN BEST RIVET.	Rolled bars $^{3}/_{4}$ in. round.	·75	·4417	621	59,900	59,219	·70
240		" "		"	"	614	59,457		·70
241		" "		"	"	607	59,013		·71
242		" "		"	"	599	58,506		·70
243		ST. ROLLOX BEST RIVET.	Rolled bars $^{13}/_{16}$ in. round.	·81	·5185	951	68,848	56,981	·77
244		" "		"	"	715	56,104		·75
245		" "		"	"	708	55,726		·77
246		" "		"	"	551	47,248		·80
247		R. SOLLOCH E. BEST.	Rolled bars $^{11}/_{16}$ in. for rivets.	·70	·3848	490	59,226	57,425	·65
248		" "		"	"	484	58,789		·66
249		" "		"	"	454	56,606		·66
250		" "		"	"	433	55,078		·65
251	Lancashire	ULVERSTON RIVET BEST.	Rolled bars $^{3}/_{4}$ in. round.	·75	·4417	612	59,330	53,775	·67
252		" "		"	"	591	58,000		·65
253		" "		"	"	591	58,000		·68
254		" "		"	"	540	54,766		·65
255		" "		"	"	505	52,547		·69
256		" "		"	"	490	51,596		·70
257		" "		"	"	447	48,870		·64
258		" "		"	"	419	47,095		·68
259		MERSEY CO., BEST.	Forged from $^{3}/_{4}$ in. sq. bars.	·67	·3526	462	62,411	60,110	·64
260		" "		·71	·3958	533	60,621		·68
261		" "		·70	·3848	505	60 317		·67
262		" "		·74	·4300	590	59,512		·71
263		" "		·74	·4300	562	57,690		·71

cept those marked *Samples*, which were received from the Makers.
racture; *s*, size at smallest part.

e between al and ed Areas.		Breaking Wght per sq. in of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght. per sq in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
			Diameter	Area.									Crys	Col	Kind
9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
. in	℔ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	℔ ct.	lbs.	inch.	inch.	in.	℔ ct.	℔ct.		
255	16·2	70,260	·82 ·78 ·75 ·75 ·76	·5281 ·4779 ·4417 ·4417 ·4586	·2573 ·3075 ·3437 ·3126 ·3162	·3075	39·6	97,548	1·64 1·97 1·92 1·88 1·87	1·86	8·0	23·2	5 1 0 1 0	Brightish-grey; fibre close and generally uniform	S S S S S
838	12·6	67,404	·71 ·71 ·72 ·72	·3955 ·3958 ·4071 ·4071	·2792 ·2792 ·2579 ·2579	·2685	40·3	97,559	1·40 1·38 1·22 1·14	1·28	6·0	21·3	0 0 0 0		S S S S
887	14·9	67,103	·64 ·67 ·68 ·69	·3216 ·3526 ·3632 ·3739	·2729 ·2419 ·2313 ·2206	·2417	40·7	96,205	1·19 1·28 1·40 1·26	1·28	5·4	23·7	1 0 0 3		S S S S
006	13·1	68,003	·65 ·62 ·67 ·59 ·75	·3318 ·3019 ·3526 ·2734 ·4417	·1461 ·1638 ·1131 ·1337 ·0485	·1210	26·2	80,053	0·67 0·75 0·62 0·80 0·53	0·67	3·2	20·9	3 0 52 0*r* 68		S S Y S Y
519	11·5	67,333	·60 ·60 ·59 ·60	·2827 ·2827 ·2734 ·2827	·1709 ·1709 ·1802 ·1590	·1702	37·7	95,706	1·27 1·40 1·47 1·45	1·40	8·3	16·9	0 0 0 0		S S S S
585	13·2	70.893	·57 ·59 ·60 ·64	·2552 ·2734 ·2827 ·3216	·1865 ·1683 ·1590 ·1201	·1585	35·9	96,267	1·56 1·72 1·44 1·17	1·47	6·8	21·6	0 0 0 0*r*		S S S S
541	12·2	67,505	·59 ·65 ·61 ·59	·2734 ·3318 ·2922 ·2734	·1683 ·1099 ·1595 ·1683	·1515	34·3	89,279	1·34 1·30 1·25 1·40	1·32	6·8	19·4	0 0 0 0		S S S S
496	9·6	63,325	·65 ·67 ·67 ·79	·3318 ·3526 ·3526 ·4902	·1867 ·1651 ·1659 ·0283	·1367	26·3	77,383	1·52 1·48 1·03 0·50	1·13	6·8	16·6	90 0 0 80*b*		Y S S Y
473	12·4	65,490	·52 ·60 ·52 ·51	·2124 ·2827 ·2124 ·2043	·1724 ·1021 ·1724 ·1805	·1568	40·7	96,959	1·51 0·88 1·00 1·28	1·17	6·6	17·7	0 2 0 0	Brightish-grey; fibre close	S S S S
888	20·1	67,324	·50 ·52 ·50 ·52 ·57 ·60 ·50 ·58	·1963 ·2124 ·1963 ·2124 ·2552 ·2827 ·1963 ·2642	·2454 ·2293 ·2454 ·2293 ·1865 ·1590 ·2454 ·1775	·2147	48·6	104,680	1·57 1·69 1·38 1·58 1·26 1·20 1·60 1·29	1·45	6·7	21·6	0 0 0 0 0 0 0 0		P P P Q Q Q P Q
328	8·2	65,394	·53 ·60 ·61 ·67 ·55	·2207 ·2827 ·2922 ·3526 ·2376	·1319 ·1131 ·0926 ·0774 ·1924	·1215	30·5	86,295	0·60 0·68 0·58 0·64 1·03	0·71	4·2	16·9	0 0*r* 9*r* 65 0		Q Q U X Q

TABLE

Note.—All the pieces were taken *promiscuously* from Engineers' or M
***b* denotes bad fracture; *r*, sligh**

Index No.	District.	Names of the Makers or Works.	Description	ORIGINAL. Diameter.	ORIGINAL. Area	Weight on Steelyd.	Breaking Weight per square inch of Original Area.		STRE Diame
				1. inch	2. sq. in.	3. lbs.	4. lbs.	5. lbs.	6. inch.
264	Swedish	Per Eckman & Co., RF Gothenburg.	4 Flat Tilted Bars, Strips cut off.	·91 × ·64	·5824	695	48,987	**47,855**	·84 ×
265		" "		·89 × ·66	·5874	676	47,664		·82 ×
266		" "		·89 × ·64	·5696	640	47,384		·79 ×
267		" "		·89 × ·64	·5696	640	47,384		·82 ×
268		Do. Do.	Forged round.	·91	·6504	826	49,505	**48,232**	·86
269		" "		·93	·6808	868	49,022		·85
270		" "		·92	·6650	805	47,534		·86
271		" "		·90	·6362	741	46,869		·85
272	Russian	Prince Demidoff, CCND	4 Flat Tilted Bars. Strips cut off.	·89 × ·57	·5073	676	55,190	**49,564**	·84 ×
273		" "		·91 × ·52	·4732	505	49,049		·89 ×
274		" "		·89 × ·55	·4895	540	49,418		·81 ×
275		" "		·88 × ·55	·4840	447	44,600		·85 ×
276		Do. Do.	Forged round.	·91	·6504	1105	65,516	**56,805**	·88
277		" "		·95	·7088	1105	56,447		·90
278		" "		·92	·6650	933	52,923		·88
279		" "		·92	·6650	919	52,334		·80
280	From Forge	Hammered Scrap Iron.		·76	·4536	552	54,070	**53,420**	·68
281		" "		·75	·4418	524	53,739		·67
282		" "		·76	·4536	538	53,205		·68
283		" "		·77	·4657	552	52,665		·68
284		Busheled Iron from Turnings.		·76	·4536	608	57,526	**55,878**	·70
285		" "		·75	·4418	580	57,290		·70
286		" "		·75	·4418	538	54,626		·69
287		" "		·76	·4536	552	54,070		·70
288	a Length of St.	Cut out of a Crank-shaft of Hammered Scrap Iron, thus—		·88	·6082	755	49,671	**47,582**	·82
289	b	 Shaft Crank a b c d e f g h 2´·6"		·87	·5945	685	47,519		·82
290	c			·87	·5945	720	49,167		·81
291	d			·86	·5812	615	45,234		·81
292	e			1·00	·7854	1007	47,459		·92
293	f			1·00	·7854	979	46,450		·94
294	g Cross.	and reduced to the required shape in the lathe, not on the anvil.		1·00	·7854	930	44,703	**44,578**	·94
295	h			1.00	·7854	923	44,453		·95

Contin

, except those marked *Samples*, which were received from the Makers.
at fracture; *s*, size at smallest part.

	erence between Original and Stretched Areas.		Breaking Wght per sq. in of Stretched Area	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght per sq in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
				Diameter	Area.									Crys	Col.	Kind
	9. sq. in	10. ⅌ ct.	11. lbs.	12. inch.	13. sq. in.	14. sq. in.	15. sq. in.	16. ⅌ ct.	17. lbs.	18. inch.	19. inch.	20. in.	21. ⅌ ct.	22. ⅌ ct.	23.	24.
5 0 2 0	·0969	16·8	57,484	·57 × ·37 ·59 × ·44 ·52 × ·35 ·62 × ·42	·2109 ·2596 ·1820 ·2604	·3715 ·3278 ·3876 ·3092	·3490	60·5	121,065	1·42 1·74 2·03 1·50	1·67	6·0	27·8	0 0 0 0	Bright light-grey; fibre very soft.	K K K K
2 4 8 8	·0838	12·7	55,285	·51 ·55 ·50 ·51	·2043 ·2376 ·1963 ·2043	·4461 ·4432 ·4687 ·4319	·4475	68·0	150,760	1·82 1·80 2·07 1·72	1·85	7·0	26·4	0 0 0 0		K K K K
1 2 5 5	·0521	10·7	55,559	·83 × ·52 ·89 × ·50 ·55 × ·36 ·60 × ·42	·4316 ·4450 ·1980 ·2520	·0757 ·0282 ·2915 ·2320	·1568	32·1	73,118	0·48 0·29 1·52 0·90	0·80	6·0	13·3	0 65*b* 0*r* 8*rr*	Bright grey; very irregular.	
2 6 8 4	·0635	12·4	63,695	·88 ·90 ·71 ·61	·6082 ·6362 ·3958 ·2922	·0422 ·0726 ·2692 ·3728	·1892	28·1	77,632	0·57 0·40 1·20 1·53	0·92	6·0	15·3	100 90*r* 0*br* 0*r*		Z Z K K
4 2 4 5	·0931	20·5	67,218	·57 ·56 ·58 ·58	·2552 ·2462 ·2642 ·2642	·1984 ·1956 ·1894 ·2015	·1962	43·2	94,105	0·93 0·98 0·92 0·93	0·94	3·8	24·8	0 0 0 0	Brightish grey; fibre close and fine.	P P P P
8 0 9 8	·0656	14·7	65,470	·68 ·65 ·64 ·68	·3632 ·3318 ·3216 ·3632	·0904 ·1100 ·1202 ·0904	·1028	22·9	72,531	0·66 0·84 0·81 0·60	0·73	4·4	16·6	5 8 3 3		U U U U
1 4 2 9 4 4	·0839	12·8	53,610	·80 ·81 ·75 ·76 ·85 ·91	·5026 ·5153 ·4417 ·4536 ·5674 ·6504	·1056 ·0792 ·1528 ·1276 ·2180 ·1350	·1364	20·7	59,003	0·67 0·60 0·86 0·70 1·18 0·83	0·71 1·00	3·7 3·7	19·2 27·0	85 80*r* 80 55*r* 70 63	White and lustrous.	W W W W W W
4 6	·0840	10·7	49,917	·92 ·95	·6650 ·7088	·1204 ·0766	·0985	12·5	50,971	0·71 0·54	0·62	3·7	16·8	60 60		W W

ges 132, 133.

Note.—All the pieces were taken *promiscuously* from Engineers' or

L denotes that the strain was applied *lengthways* of the plate; C, *crossways; f*, size at fract

Index No.	District.	Names of the Makers or Works	See Note.	ORIGINAL. Thick 1. inch.	ORIGINAL. Bdth 2. inch.	ORIGINAL. Area 3. sq. in.	Weight on Steelyd 4. lbs.	Breaking Weight per square inch of Original Area 5. lbs.	6. lbs.	7. lbs.	FRAC Thick 8. inch.
301	Sheffield	T. Turton & Sons. Cast Steel.	L	·260 ×	2·00	·520	1447	95,360	94,289	95,299	255 ×
302		″ ″	″	·270 ×	2·00	·504	1511	95,144			·259 ×
303		″ ″	″	·260 ×	2·00	·520	1418	93,796			·255 ×
304		″ ″	″	267 ×	2·00	·534	1447	92,858			·259 ×
305		″ ″	C	·272 ×	2·00	·544	1618	99,952	96,308		·245 ×
306		″ ″	″	·268 ×	2·00	·536	1562	98,519			·238 ×
307		″ ″	″	·268 ×	2·00	·536	1475	93,974			·245 ×
308		″ ″	″	·250 ×	2·00	·500	1333	92,788			·248 ×
309		Naylor, Vickers, & Co. Cast Steel.	L	·250 ×	2·00	·500	1247	87,972	81,719	84,435	·230 ×
310			″	″	″	″	1219	86,404			·226 ×
311		″ ″	″	″	″	″	1133	81,588			·225 ×
312		″ ″	″	″	″	″	1090	79,180			·212 ×
313		″ ″	Samples ″	″	″	″	1076	78,396			·200 ×
314		″ ″	″	″	″	″	1047	76,772			·205 ×
315		″ ″	C	·250 ×	2·00	·500	1376	95,196	87,150		·224 ×
316		″ ″	″	″	″	″	1347	93,572			·230 ×
317		″ ″	″	″	″	″	1190	84,780			·218 ×
318		″ ″	″	″	″	″	1172	83,772			·220 ×
319		″ ″	″	″	″	″	1161	83,156			·220 ×
320		″ ″	″	″	″	″	1148	82,428			·218 ×
321		Moss & Gambles, Cast Steel.	L	·250 ×	2·00	·500	1133	81,588	75,594	72,338	·216 ×
322			″	·250 ×	2·00	·500	1105	80,020			·198 ×
323		″ ″	″	·238 ×	2·00	·476	1035	79,937			·211 ×
324		″ ″	″	·172 ×	2·00	·344	619	76,750			·138 ×
325		″ ″	″	·188 ×	2·00	·376	647	72,303			·140 ×
326		″ ″	″	·262 ×	2·00	·524	997	70,584			·196 ×
327		″ ″	″	·230 ×	1·87	·430	720	67,977			·203 ×
328		″ ″	C	·262 ×	1·99	·521	1012	71,793	69,082		·200 ×
329		″ ″	″	·262 ×	2·00	·524	947	67,912			·210 *m*
330		″ ″	″	·262 ×	2·00	·524	949	67,538			·180 ×
331		Shortridge, Howell, & Co. Homogeneous Metal,	L	·190 ×	2·00	·380	1151	108,900	96,280	96,715	·183 ×
332			″	·180 ×	2·00	·360	976	101,105			·176 ×
333			″	·190 ×	1·99	·378	990	97,328			·178 ×
334			″	·190 ×	2·00	·380	876	88,416			·156 ×
335		″ ″	″	·190 ×	1·87	·355	762	85,650			·148 ×
336		″ ″	C	·190 ×	2·00	·380	1111	105,732	97,150		·178 ×
337		″ ″	″	″	″	″	1033	99,984			·178 ×
338		″ ″	″	″	″	″	1019	98,953			·165 ×
339		″ ″	″	″	″	″	991	96,868			·179 ×
340		″ ″	″	″	″	″	819	84,211			·165 ×
341		Do. Do.	C	·375 ×	2·00	·750	2274	96,989			·338 ×
342		Do. Do. Second Quality.	L	·240 ×	2·00	·480	1076	81,662	72,403	72,994	·220 ×
343			″	·250 ×	2·00	·500	1032	75,932			·238 ×
344		″ ″	″	·250 ×	2·00	·500	919	69,604			·230 ×
345		″ ″	Samples ″	·250 ×	1·95	·487	762	62,435			·230 ×
346		″ ″	C	·250 ×	2·00	·500	1189	84,724	73,580		·244 ×
347		″ ″	C	·250 ×	1·95	·487	762	62,435			·238 ×

except those marked *Samples*, which were received from the Makers
lest part; *m*, mean size; *d* denotes that the layers are slightly disunited; *b*, bad fracture.

Difference between ractured and Original Areas.				Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.	
												Gran.	Kind.
12. sq.in.	13. sq.in.	14. ℔ ct.	15. ℔ ct.	16. lbs.	17. lbs.	18. inch.	19. inch.	20. inch.	21. inch.	22. ℔ ct.	23. ℔ ct.	24. ℔ cent.	25.
	·050		9·5		105.937	·30		·430	5·6		7·68	100	A
029		5.6		100,063		·33	·32			5·71		100	A
						·27						100	A
						·40						100	B
						.67						100	C
071		13.4		111,811		·69	·54			9·64		100	C
						·52						100	C
						·28						100	A
	·109		21·7		108,125	0·82		·975	5·6		17·41	76	D
						0·96						100	B
107		21·4		104,232		0·80	·98			17·50		65	D
						1·08						0	E
						1·13						0	F
						1·10						0	E
						0·93						80	D
						0·90						62	D
111		22·0		112,018		1·13	·97			17·32		0	H
						0·90						0	E
						0·88						0	H
						1·10						0	E
	·164		33·4		109,050	1·06		1·105	5·6		19·73	0	E
						1·03						0	F
						1·10						0	E
127		28·2		105,554		1·17	1·11			19·82		0	F
						1·06						0	F
						1·07						0	G
						1·27						0	F
						1·10						0	F
202		38·6		112,546		1·05	1·10			19·64		0	G
						1·16						0	H
	·057		15·2		114.203	27		·491	5·6		8·77	100	A
						·18						100	A
058		15·6		114,106		·28	482			8·61		100	A
						·68						0	F
						·99						0	G
						·40						100	B
						·45						83	D
·056		14·8		114,300		·70	·500			8·93		60	D
						·35						95	B
						·60						0	F
		14·4		113,305		·52			3·6	14·4		100	C
	·042		8·6		80.034	·43		·256	5·6		4·57	0	J
						·20						0	J
057		11·5		81,823		·42	·332			5·93		0	J
						·28						0	J
028		5·7		78,245		·20	·180			3.21		10	I
						·16						1	J

NOTE.—All the pieces were taken *promiscuously* from Engineers' or
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fract

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL.			Weight on Steelyd.	Breaking Weight per square inch of Original Area.			FRAC
				Thick.	Bdth	Area					Thick.
				1. inch.	2. inch.	3. sq. in.	4. lbs.	5. lbs.	6. lbs.	7. lbs.	8. inch.
348	Liverpool	MERSEY Co. Puddled Steel (Ship Plates.)	L	·180 ×	1·88	·338	990	108,906	101,450	93,209	·176 ×
349			〃	·180 ×	1·90	·342	961	105,199			·169 ×
350			〃	·115 ×	1·90	·218	447	99,019			·109 ×
351		〃 〃	〃	·115 ×	1·88	·216	391	92,676			·110 ×
352		〃 〃	C	·180 ×	1·90	·342	891	99,468	84,968		·173 ×
353		〃 〃	〃	·180 ×	1·88	·338	748	88,800			·172 ×
354		〃 〃	〃	·115 ×	1·89	·217	362	88,507			·112 ×
355		〃 〃	〃	·102 ×	1·89	·193	111	63,098			·101 ×
356		MERSEY Co. Puddled Steel, "Hard."	Samples L	·245 ×	2·00	·490	1533	106,110	102,593	93,979	·238 ×
357			〃	·250 ×	2·00	·500	1564	105,724			·244 ×
358			〃	·250 ×	1·94	·485	1338	95,946			·244 ×
359		〃 〃	C	·250 ×	1·95	·488	1219	88,529	85,365		·248 ×
360		〃 〃	〃	·250 ×	2·00	·500	1144	82,200			·244 ×
361		Do. "Mild" Do.	L	·250 ×	2·00	·500	1228	86,908	77,046	72,366	·234 ×
362		〃 〃	〃	·250 ×	1·95	·488	847	67,184			·230 ×
363		〃 〃	C	·250 ×	1·95	·488	876	68,848	67,686		·237 ×
364		〃 〃	〃	·250 ×	2·00	·500	864	66,524			·235 ×
365		Do. Do. (Ship Plates.)	L	·275 ×	1·79	·492	1047	78,020	71,532		·258 ×
366		〃 〃	L	·275 ×	1·79	·492	819	65,045			·250 ×
367	Glasgow	BLOCHAIRN Puddled Steel.	Samples L	·190 ×	2·00	·380	1120	106,394	102,234	93,316	·186 ×
368			〃	·190 ×	2·00	·380	1118	106,247			·181 ×
369		〃 〃	〃	·190 ×	2·00	·380	1076	103,152			·180 ×
370		〃 〃	〃	·190 ×	2·00	·380	1061	102,047			·188 ×
371		〃 〃	〃	·180 ×	2·00	·360	876	93,827			·173 ×
372		〃 〃	C	·190 ×	2.00	·380	890	89,447	84,398		·186 ×
373		〃 〃	〃	〃	〃	〃	826	84,710			·180 ×
374		〃 〃	〃	〃	〃	〃	826	84,710			·189 ×
375		〃 〃	〃	〃	〃	〃	790	82,079			·180 ×
376		〃 〃	〃	〃	〃	〃	776	81,047			·189 ×
377		Do. Do. (Boiler Plates.)	L	·312 ×	2·00	·624	1847	97,413	96,320	85,010	·300 ×
378			〃	·312 ×	1·75	·546	1533	95,227			·286 ×
379		〃 〃	C	·312 ×	2·00	·624	1361	75,606	73,699		·309 ×
380		〃 〃	〃	·312 ×	2·00	·621	1276	71,792			·300 ×

ccept those marked *Samples*, which were received from the Makers.
st part; *m*, mean size; *d* denotes that the layers are slightly disunited; *b*, bad fracture.

ifference between ctured and Original Areas.				Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.	
												Gran.	Kind
.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	26.
in.	sq. in.	℘ ct.	℘ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	℘ ct.	℘ ct.	℘ cent.	
18	·015	6·4	5·4	109,552	100,649	·16	·212	·153	7·6	2·79	2·02	38	I
						·24						24	I
						·22						2	J
						·23						0	J
12		4·4		91,746		·10	·095			1·25		30	I
						·08						8	J
						·15						1	J
						·05						0*b*	J L
22	·022	4·5	4·6	107,827	98,472	·28	·272	·228	5·6	4·86	4·08	85	I A
						·20						90	I A
						·34						52	I A
13		4·7		89,116		·13	·185			3·30		62	I A
						·24						55	I A
62	·052	12·5	10·5	88,240	80,937	·36	·345	·332	5·6	6·16	5·94	33	I
						·33						0	J
62		8·5		73,634		·31	·320			5·72		2	J
						·33						0	J
57		7·5		77,520		·22	·200		5·6	3·57		1	J
						·18						0*d*	J
30	·018	5·3	4·8	108,079	97,978	·22	·202	·176	5·6	3·60	3·14	82	I A
						·26						85	I A
						·30						65	I A
						·15						78	I A
						·08						80	I A
16		4·2		87,877		·28	·150			2·68		88	I
						·18						28	I
						·07						90	I A
						·14						5	J
						·08						85	I K
51	·042	10·4	7·1	107,614	92,130	·51	·625	·470	7·6	8·22	6·18	44	K
						·74						2	L
24		3·8		76,646		·22	·315			4·14		30	K
						·41						5	L

TABL

Note.—All the pieces were taken *promiscuously* from Engineers' or

L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fractur

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL. Thick.	ORIGINAL. Bdth	ORIGINAL. Area	Weight on Steelyd	Breaking Weight per square Inch of Original Area.			FRA Thick. B
				1. inch.	2. inch.	3. sq. in.	4. lbs.	5. lbs.	6. lbs.	7. lbs.	8. inch.
401	Yorkshire	Lowmoor.	L	·312 ×	2·00	·624	966	57,881	52,000	51.257	·255 ×
402		〃 〃	〃	〃 ×	1·80	·562	763	54,153			·275 ×
403		〃 〃	〃	〃 ×	1·78	·555	678	50,548			·260 ×
404		〃 〃	〃	〃 ×	2·00	·624	790	49,986			·260 ×
405		〃 〃	〃	〃 ×	2·00	·624	733	47,426			·275 ×
406		〃 〃	C	〃 ×	2·00	·624	910	55,368	50,515		·275 ×
407		〃 〃	〃	〃 ×	1·78	·555	720	52,669			·275 ×
408		〃 〃	〃	〃 ×	2·00	·624	761	48,682			·295 ×
409		〃 〃	〃	〃 ×	1·78	·555	636	48,429			·300 ×
410		〃 〃	〃	〃 ×	2·00	·624	733	47,426			·287 ×
411		Bowling.	L	·395 ×	1·78	·703	1019	53,488	52,235	49.338	·362 ×
412		〃 〃	〃	·400 ×	1·80	·720	1033	52,770			·362 ×
413		〃 〃	〃	·325 ×	2·00	·650	883	51,991			·280 ×
414		〃 〃	〃	.400 ×	2·00	·800	1147	51,485			·345 ×
415		〃 〃	〃	·375 ×	2·00	·750	1054	51,443			·330 ×
416		〃 〃	C	·375 ×	2·00	·750	1019	50,136	46,441		·350 ×
417		〃 〃	〃	·412 ×	1·78	·733	933	48,014			·388 ×
418		〃 〃	〃	·400 ×	1·78	·712	846	46,008			·392 ×
419		〃 〃	〃	·400 ×	2·00	·800	961	44,972			·375 ×
420		〃 〃	〃	·325 ×	2·00	·650	676	43,074			·312 ×
421		Farnley.	L	·375 ×	2·00	·750	1304	59,443	56,005	51.113	·320 × 1
422		〃 〃	〃	·375 ×	2·00	·750	1219	57,602			·350 × 1
423		〃 〃	〃	·375 ×	2·00	·750	1161	55.437			·320 × 1
424		〃 〃	〃	·355 ×	2·00	·710	983	51,541			·295 × 1
425		〃 〃	C	·375 ×	2·00	·750	1019	50,136	46,221		·338 × 1
426		〃 〃	〃	·375 ×	2·00	·750	990	49,054			·325 × 1
427		〃 〃	〃	·355 ×	2·00	·710	821	45,152			·330 × 1
428		〃 〃	〃	·375 ×	2·00	·750	762	40,541			·345 × 1
429		Do. Do.	L	·245 ×	2·00	·490	747	61,184	58,487	56,292	·196 × 1
430		〃 〃	〃	·259 ×	〃	·518	761	58,645			·212 × 1
431		〃 〃	〃	·230 ×	〃	·460	590	55,631			·208 × 1
432		〃 〃	C	·250 ×	〃	·500	761	60,756	54,098		·230 × 1
433		〃 〃	〃	·245 ×	〃	·490	733	60,396			·215 × 1
434		〃 〃	〃	·250 ×	〃	·500	619	52,804			·237 × 1
435		〃 〃	〃	·245 ×	〃	·490	562	50,625			·228 × 1
436		〃 〃	〃	·250 ×	〃	·500	576	50,396			·230 × 1
437		〃 〃	〃	·250 ×	〃	·500	562	49,612			·245 × 1
438		Do. Do.	Samples L	·750 ×	1·50	1·125	2189	62,544	58,437	56,735	·645 × 1
439		〃 〃	〃	〃 ×	〃	1·125	2034	58,686			·590 × 1
440		〃 〃	〃	〃 ×	〃	1·125	1940	56,347			·600 × 1
441		〃 〃	〃	〃 ×	〃	1·125	1933	56,172			·625 × 1
442		〃 〃	C	〃 ×	〃	1·125	1948	56,546	55,033		·635 × 1
443		〃 〃	〃	〃 ×	〃	1·125	1948	56.546			·660 × 1
444		〃 〃	〃	〃 ×	〃	1·125	1849	54.082			·620 × 1
445		〃 〃	〃	·745 ×	1·47	1·095	1747	52,955			·670 × 1
446	Durham	Consett.	L	·780 ×	1·62	1·264	2132	54,403	51,245	48.979	·705 × 1
447		〃 〃	〃	·775 ×	1·62	1·256	1996	51,718			·712 × 1
448		〃 〃	〃	·780 ×	1·40	1·092	1533	47,613			·698 × 1
449		〃 〃	C	·780 ×	1·40	1·092	1533	47,613	46,712		·705 × 1
450		〃 〃	〃	·840 ×	1·00	0·840	1076	46,664			·775 × 0
451		〃 〃	〃	780 ×	1·40	1·092	1490	46,511			·737 × 1
452		〃 〃	〃	·775 ×	1·40	1·085	1461	46,062			·710 × 1

N PLATES.

, except those marked *Samples*, which were received from the Makers.
st part; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

Difference between ractured and Original Areas.				Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
												Crys.	Col.	Kind
12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
sq.in.	sq.in.	₩ ct.	₩ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	₩ ct.	₩ ct.	₩ ct.		
·118	·095	19·7	15·9	64,746	61,065	·84	·74	0·63	5·6	13·2	11·25	0	Colour generally uniform, of a light brightish-grey; fibre compact and very fine: 428 dark-grey	M
						·82						0		M
						·76						0		M
						·72						0		M
						·54						0*i*		M
·072		12·1		57,383		·60	·52			9·3		3		O
						·60						0		O
						·40						0		O
						.52						0		O
						·46						0		O
111	·080	15·3	11·1	61,716	55,862	·50	·65	0·49	5·6	11·6	8·75	45		Q
						·43						30		Q
						·69						1*i*		M
						·84						0*i*		M
						·78						0		M
·050		6·9		50,009		·58	·33			5·9		0		O
						·27						20		Q O
						·20						10		Q O
						·33						0		P
						·25						0*i*		P
·132	·115	17·8	15·5	68,763	61,028	1·03	1·07	0·82	7·6	14·1	10·85	1		M
						1·06						4		M Q
						1·00						0		M
						1·20						0		M
·098		13·2		53,293		0·58	0·58			7·6		0		O
						0·70						0		O
						0·72						0*i*		O
						0·33						0*bi*		P
097	·072	20·0	15·7	70,538	65,118	1·04	0·83	0·64	7·6	10·9	8·40	0		M
						0·77						0		M
						0·68						0*i*		M
·046		11·4		59,698		0·58	0·45			5 9		0		O
						0·68						0		O
						0·27						0*i*		O
						0·49						0		O
						0·41						0		O
						0·24						0*i*		O
333	·279	29·6	24·8	83,112	76,036	1·25	1·29	1·07	7·6	17·0	14·15	0		M
						1·51						0		M N
						1·38						15		N Q
						1·03						0		M N
225		20·1		68,961		0·90	0·86			11·3		55		Q
						0·90						8		N Q
						1·03						0*i*		O N
						0·60						45*i*		Q
·158	·131	13·1	11·7	59,183	55.616	0·58	0·50	0·43	5·6	8·93	7·68	45*i*	Grey; fibre loose.	S V
						0·54						30*i*		S V
						0·38						50		S V
·105		10·2		52.050		0 40	0·36			6·43		35*i*		S V
						0·50						22*ib*		V
						0·28						6		V
						0·26						46		S V

TABL

NOTE.—All the pieces were taken *promiscuously* from Engineers' or

L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL			Weight on Steelyd.	Breaking Weight per square inch of Original Area.			FRACT
				Thick.	Bdth.	Area.					Thick.
				1.	2.	3.	4.	5.	6.	7.	8.
				inch.	inch.	sq. in.	lbs.	lbs.	lbs.	lbs.	inch.
453	Staffordshire	J. Bradley & Co., S.C. ♔	L	·480 ×	2·00	0·960	1683	58,534	**55,831**	**53,191**	·410 ×
454			″	·500 ×	1·99	0·995	1633	55,070			·440 ×
455		″ ″	″	·500 ×	1·99	0·995	1591	53,889			·470 ×
456		″ ″	C	·480 ×	2·00	0·960	1576	55,414	**50,550**		·445 ×
457		″ ″	″	·506 ×	1·98	1·002	1419	48,705			·470 ×
458		″ ″	″	·500 ×	1·99	0·995	1333	47,532			·480 ×
459		Do. L F Do.	L	·350 ×	1·78	·623	1083	60,985	**56,996**	**54,123**	·312 ×
460		″ ″	″	·412 ×	1·80	·742	1276	60,374			·362 ×
461		″ ″	″	·388 ×	1·99	·772	1218	55,925			·345 ×
462		″ ″	″	·350 ×	1·78	·623	904	55,188			·312 ×
463		″ ″	″	·392 ×	2·00	·784	1211	54,819			·355 ×
464		″ ″	″	·470 ×	2·00	·940	1512	54,687			·438 ×
465		″ ″	C	·415 ×	1·80	·747	1162	55,697	**51,251**		·387 ×
466		″ ″	″	·370 ×	1·80	·666	961	54,021			·350 ×
467		″ ″	″	·480 ×	1·99	·955	1447	51,922			·455 ×
468		″ ″	″	·370 ×	1·75	·647	819	49,462			·337 ×
469		″ ″	″	·400 ×	2·00	·800	1076	48,997			·388 ×
470		″ ″	″	·388 ×	2·00	·776	990	47,410			·362 ×
471		Do. Do.	L	·500 ×	1·99	0·995	1833	60,697	**55,708**	**52,566**	·455 ×
472		″ ″	″	·390 ×	1·99	0·776	1204	55,131			·350 ×
473		″ ″	″	·390 ×	2·00	0·780	1105	51,295			·350 ×
474		″ ″	C	·512 ×	1·99	1·019	1533	51,025	**49,425**		·488 ×
475		″ ″	″	·400 ×	2·00	0·800	1105	50,012			·375 ×
476		″ ″	″	·400 ×	1·99	0·796	1019	47,238			·378 ×
477		T. Wells, Best Best.	L	·500 ×	1·97	0·985	1590	54,406	**47,410**	**47,020**	·462 ×
478		″ ♔ ″	″	·500 ×	1·65	0·825	1276	54,301			·475 ×
479		″ ″	″	·510 ×	1·99	1·015	1447	48,853			·480 ×
480		″ ″	″	·510 ×	1·72	0·877	1105	45,621			·490 ×
481		″ ″	″	·510 ×	1·72	0·877	1105	45,621			·490 ×
482		″ ″	″	·306 ×	1·99	0·609	591	42,066			·298 ×
483		″ ″	″	·304 ×	1·99	0·605	562	41,002			·296 ×
484		″ ″	C	·505 ×	1·97	0·995	1433	49,441	**46,630**		·494 ×
485		″ ″	″	·500 ×	2·00	1·000	1433	49,194			·470 ×
486		″ ″	″	·505 ×	2·00	1·010	1426	48,513			·480 ×
487		″ ″	″	·505 ×	1·99	1·005	1361	46,943			·485 ×
488		″ ″	″	·500 ×	2·00	1·000	1333	46,394			·485 ×
489		″ ″	″	·300 ×	1·97	0·591	591	43,347			·292 ×
490		″ ″	″	·310 ×	2·00	0·620	619	42,581			·302 ×
491		K. B. M.	L	·312 ×	2·00	·624	820	51,285	**46,404**	**46,584**	·290 ×
492		″	″	·312 ×	1·78	·555	562	44,696			·300 ×
493		″	″	·312 ×	1·78	·555	533	43,232			·290 ×
494		″	C	·312 ×	1·78	·555	576	45,402	**44,764**		·290 ×
495		″	″	·312 ×	1·78	·555	562	44,696			·300 ×
496		″	″	·312 ×	2·00	·624	661	44,195			·305 ×
497	Lanarkshire.	Mossend, Best Best.	L	·400 ×	2·00	·800	933	43,992	**43,433**	**42,445**	·380 ×
498		″ ″	″	·410 ×	2·00	·820	944	43,295			·395 ×
499		″ ″	″	·400 ×	2·00	·800	905	43,012			·380 ×
500		″ ″	C	·410 ×	2·00	·820	961	43,875	**41.456**		·385 ×
501		″ ″	″	·400 ×	2·00	·800	890	42,487			·385 ×
502		″ ″	″	·400 ×	2·00	·800	762	38,007			·390 ×

PLATES—(*Continued*).

ıt those marked *Samples*, which were received from the Makers.
:; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

rence between red and Original Areas.			Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
											Crys.	Col.	Kind.
13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
sq. in.	℔ ct.	℔ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	℔ ct.	℔ ct.	℔ ct.		
·130	17·2	13·1	67,406	61,306	·88 ·65 ·58	·70	·51	5·6	12.5	9·00	5 0*i* 3*i*	Dullish-grey, of various shades; fibre, close and generally fine.	N N N
	9·0		55,206		·38 ·36 ·20	·31			5·5		8 1*i* 1		N V N V N V
·089	15·0	11·8	66,858	61,464	·82 ·80 ·68 ·74 ·77 ·56	·73	·53	5·6	13·0	9·45	10 15 40 3 0 5		N S N S N S N N N
	8·6		56,070		·35 ·30 ·40 ·38 ·25 ·30	·33			5·9		10*i* 30 1*i* 5 5 1		N V S V N V N V N V N V
·099	14·9	11·5	65,652	59,827	·58 ·75 ·47	·60	·45	5·6	10·7	7·90	50 1 1		S N N N
	8·1		54,002		·32 ·30 ·27	·29			5·1		40 5 1		S N V N V
·050	6·7	5·8	51,521	49 935	·50 ·38 ·42 ·29 ·27 ·13 ·08	·30	·28	7·6	4·0	3·70	23 20 4 2*i* 2 9*i* 10*ii*	Dull-grey; fibre, rather coarse	U U U U U U U
	4·9		48,348		·23 ·40 ·42 ·30 ·17 ·08 ·25	·26			3·4		30*i* 10 4 10 15 1*i* 1		V S V V V V V V
·048	10·2	8·3	51,896	49,893	·46 ·28 ·28	·34	·29	5·6	6·1	5·20	3 0*i* 0*bi*		U U U
	6·4		47,891		·33 ·26 ·14	·24			4·3		0*i* 1*ii* 15*ii*		V V V
·043	5·7	5·3	46,038	44,830	·27 ·23 ·24	·25	·24	7·6	3·3	3·10	2 30 35*i*	Grey; coarse.	W WR WR
	4·9		43,622		·32 ·23 ·12	·22			2·9		20 25 2*i*		WR WR W

TABL

Note.—All the pieces were taken *promiscuously* from Engineers' or
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fractur

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL Thick. Bdth	ORIGINAL Area	Weight on Steelyd	Breaking Weight per square inch of Original Area			FRACT Thick. B
				1. 2.	3.	4.	5.	6.	7.	8.
				inch. inch.	sq. in.	lbs.	lbs.	lbs.	lbs.	inch. i
503	Lanarkshire	GLASGOW, Best Boiler.	L	·400 × 1·75	0·700	1084	56,317	53,849	51,349	·362 × 1
504			〃	·660 × 2·00	1·312	2293	55,510			·620 × 1
505		〃 〃	〃	·375 × 2·00	0·750	1154	55,176			·345 × 1
506		〃 〃	〃	·375 × 2·00	0·750	1147	54,907			·350 × 1
507		〃 〃	〃	·400 × 1·78	0·712	1028	53,166			·360 × 1
508		〃 〃	〃	·580 × 1·50	0·870	1168	48,016			·532 × 1
509		〃 〃	C	·400 × 1·75	0·700	1000	52,959	48,848		·375 × 1
510		〃 〃	〃	·375 × 2·00	0·750	1033	50,659			·372 × 1
511		〃 〃	〃	·400 × 1·78	0·712	916	48,761			·362 × 1
512		〃 〃	〃	·375 × 2·00	0·750	962	48,000			·360 × 1
513		〃 〃	〃	·660 × 1·50	0 990	1336	46,947			·636 × 1
514		〃 〃	〃	·620 × 1·50	0·930	1196	45,761			·585 × 1
515		GLASGOW Ship.	L	·188 × 2·00	0·376	393	53,370	47,773	46,064	·180 × 1
516		〃 〃	〃	·637 × 1·65	1·051	1590	50,989			·620 × 1
517		〃 〃	〃	·312 × 1·97	0·615	761	49,395			·302 × 1
518		〃 〃	〃	·637 × 1·50	0·955	1304	47,730			·620 × 1
519		〃 〃	〃	·705 × 1·50	1·057	1476	47,680			·655 × 1
520		〃 〃	〃	·390 × 2·00	0·780	720	37,474			·386 × 1
521		〃 〃	C	·180 × 1·97	0·355	308	49,842	44,355		·176 × 1
522		〃 〃	〃	·312 × 1·97	0·615	761	49,395			·308 × 1
523		〃 〃	〃	·730 × 1·50	1·095	1448	45,310			·690 × 1
524		〃 〃	〃	·650 × 1·65	1·072	1390	44,766			·640 × 1
525		〃 〃	〃	·637 × 1·67	1·064	1362	44,366			·625 × 1
526		〃 〃	〃	·390 × 2·00	0·780	580	32,450			·388 × 2
527		Makers' Stamp uncertain.	L	·425 × 2·00	0·850	1189	49,838	47,598	44.140	·390 × 1
528			〃	·425 × 1·98	0·841	1161	49,439			·400 × 1
529		〃 〃	〃	·675 × 1·65	1·114	1619	48,835			·642 × 1
530		〃 〃	〃	·625 × 1·50	0·937	1308	48,766			·550 × 1
531		〃 〃	〃	·340 × 1·79	0·609	664	45,422			·305 × 1
532		〃 〃	〃	·238 × 2·20	0·476	412	43,290			·220 × 1
533		〃 〃	C	·675 × 1·65	1·114	1447	44,512	40,682		·655 × 1
534		〃 〃	〃	·625 × 1·50	·937	1084	42,072			·580 × 1
535		〃 〃	〃	·425 × 2·00	·850	905	40,482			·412 × 1
536		〃 〃	〃	·238 × 2·00	·476	357	40,055			·236 × 1
537		〃 〃	〃	·250 × 2·00	·500	384	39,644			·243 × 1
538		〃 〃	〃	·330 × 1·80	·594	468	37,330			·325 × 1
539		GOVAN Best.	L	·245 × 1·97	·483	533	49,677	43,942	41.743	·225 × 1
510		〃 〃	〃	·365 × 〃	·719	878	46,806			·350 × 1
541		〃 〃	〃	·245 × 〃	·483	476	46,373			·230 × 1
542		〃 〃	〃	·380 × 〃	·748	847	43,831			·362 × 1
543		〃 〃	〃	·505 × 〃	·995	1047	38,570			·482 × 1
544		〃 〃	〃	·360 × 〃	·709	648	38,398			·350 × 1
545		〃 〃	C	·245 × 〃	·483	419	43,069	39,544		·245 × 1
546		〃 〃	〃	·380 × 〃	·748	820	42,783			·376 × 1
547		〃 〃	〃	·505 × 〃	·995	1089	39,761			·480 × 1
548		〃 〃	〃	·365 × 〃	·719	662	38,395			·353 × 1
549		〃 〃	〃	·365 × 〃	·719	621	36,798			·362 × 1
550		〃 〃	〃	·345 × 〃	·483	305	36,460			·245 × 1

Conti

t those marked *Samples*, which were received from the Makers.

; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

rence between red and Original Areas.			Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
											Crys.	Col.	Kind.
13. sq. in.	14. ℔ ct.	15. ℔ ct.	16. lbs.	17. lbs.	18. inch.	19. inch.	20. inch.	21. inch.	22. ℔ ct.	23. ℔ ct.	24. ℔ ct.	25.	26.
·075	11·0	8·8	60,522	56,387	·47	·52	·390	5·6	9·3	6·95	75	Grey; fibre rather coarse; crystals fine.	R
					·70						65		R
					·56						65*i*		R
					·47						43		R
					·50						0		U
					·45						10*ii*		R U
	6·6		52,252		·20	·26			4·6		73		R
					·14						67		R
					·40						1		U
					·28						18		R U
					·25						45*i*		R
					·30						12		R U
034	4·8	4·1	49·816	47,580	·39	·27	·215	7·6	3·65	2·83	7	Grey; fibre coarse; crystals generally coarse.	W
					·25						86*i*		T
					·29						22		R U
					·28						60		R
					·31						45*i*		R
					·11						65*bi*		T
	3·4		45,343		·07	·16			2·11		55		R
					·18						12		W
					·35						5*i*		W
					·16						85		T
					·16						90		T
					·05						45*bi*		T W
·058	9·8	7·4	53,182	48,304	·35	·33	·235	5·6	5 9	4·20	50	Dull-grey; fibre rather coarse.	R W
					·20						45		R W
					·23						2*i*		W
					·50						1		W
					·36						0*i*		W
					·35						0		W
	5·0		43,426		·18	·14			2·5		3		W
					·25						2		W
					·08						50*ii*		T W
					·05						1*i*		W
					·14						2*i*		W
					·15						1		W
·030	6·0	4·3	45,886	43,255	·40	·26	·185	7·6	3·4	2·40	3	Grey; fibre generally coarse.	U
					·20						40*i*		W T
					·27						3		W
					·27						3		W
					·24						20*i*		W T
					·18						0*i*		W
	2·6		40,624		·03	·11			1·4		2		W
					·15						3		W
					·24						37		W R
					·13						5*i*		W
					·07						10		W
					·03						3*bi*		W

6, 137.

TABLE E

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Merchant
i denotes that the layers are rather imperfectly weld

Index No.	District.	Names of the Makers or Works.	ORIGINAL Thick. Bdth	ORIGINAL Area	Weight on Steelyd.	Breaking Weight per square inch of Original Area.		FRACTURED Thick. Bdth	FRACTURED Area
			1. 2.	3.	4.	5.	6.	8. 9.	[illegible]
			inch. inch.	sq. in.	lbs.	lbs.	lbs.	inch. inch.	[illegible]
601	Lanarkshire	GLASGOW, Ship Beam.	·500 × 1·96	·980	1792	60,455	55,937	·426 × 1·80	[illegible]
602		" "	·500 × 1·96	·980	1591	54,712		·435 × 1·85	[illegible]
603		" "	·350 × 1·97	·689	1019	54,575		·315 × 1·91	[illegible]
604		" "	·350 × 1·97	·689	1005	54,006		·315 × 1·91	[illegible]
605		DUNDYVAN, Ship Strap.	·688 × 1·66	1·142	1982	56,538	55,285	·615 × 1·57	[illegible]
606		" "	·650 × 1·67	1·085	1819	55,301		·585 × 1·60	[illegible]
607		" "	·500 × 1·72	0·860	1361	54,858		·460 × 1·67	[illegible]
608		" "	·575 × 1·66	0·955	1533	54,444		·525 × 1·61	[illegible]
609		MOSSEND, Ship Strap.	·570 × 1·97	1·123	1761	51,985	45,439	·525 × 1·89	[illegible]
610		" "	·690 × 1·00	0·690	780	44,797		·448 × 0·98	[illegible]
611		" "	1·000 × 1·00	1·000	1088	39,534		·945 × 0·98	[illegible]
612	Staffordshire.	THORNEYCROFT, Ship Strap.	·480 × 1·97	·946	1590	56,649	52,789	·445 × 1·92	[illegible]
613		" "	·470 × 1·72	·808	1276	55,443		·395 × 1·61	[illegible]
614		" "	·500 × 1·96	·980	1535	53,112		·465 × 1·89	[illegible]
615		" "	·470 × 2·00	·940	1419	51,917		·428 × 1·95	[illegible]
616		" "	·470 × 2·00	·940	1404	51,470		·428 × 1·92	[illegible]
617		" "	·500 × 1·96	·980	1361	48,141		·470 × 1·90	[illegible]
618	Durham.	CONSETT, Ship Angle-iron.	·570 *m* 1·66	·946	1533	54,962	50,807	·512 *m* 1·57	[illegible]
619		" "	·570 *m* 1·66	·946	1504	54,103		·525 *m* 1·59	[illegible]
620		" "	·528 *m* 1·72	·908	1334	51,125		·500 *m* 1·66	[illegible]
621		" "	·700 *m* 1·00	·700	752	43,037		·640 *m* 0·97	[illegible]
622	S. Wales.	DOWLAIS, Ship Beam.	·520 × 1·79	·931	1133	43,817	41,386	·478 × 1·74	[illegible]
623		" "	·530 × 1·79	·949	1146	43,370		·483 × 1·70	[illegible]
624		" "	·530 × 1·79	·949	1047	40,449		·506 × 1·75	[illegible]
625		" "	·525 × 1·97	1·034	1076	37,909		·484 × ·915	[illegible]

Continued at

es, except those marked *Samples*, which were received from the Makers.
d fracture: *s*, size at smallest part; *m*, mean thickness.

Difference between Fractured and Original Areas.			Breaking Weight per square inch of Fractured Area.	ELONGATION. Original Length of Stretched Part in Column 21.				FRACTURE.		
								Crys.	Col.	Kind.
11.	12.	14.	16.	18.	19.	21.	22.	24.	25.	26.
-in.	sq.in.	℔ cent.	lbs.	inch.	inch.	inch.	℔ ct.	℔ ct.		
214 175 087 087	·141	16·9	67,606	1·19 ·92 ·56 ·60	·82	7·6	10·79	44 12 2 3	Grey; fibre close.	R R U U U
176 149 092 110	·132	13·0	63·635	·86 ·67 ·47 ·46	·61	7·6	8·03	45 14 18i 26		R R U R U R U
131 055 074	·087	9·2	50,459	·45 ·23 ·18	·29	5·6	5·18	53 1i 90i	Grey.	R W T
092 172 101 105 118 087	·113	12·1	59,918	·49 ·98 ·68 ·48 ·60 ·45	·61	7·6	8·03	33 0 7 45i 1 2	Lightish-grey.	R N N U R N U N U
142 111 078 079	·102	11·7	58,201	·43 ·50 ·38 ·43	·44	7·6	5·79	36 1i 18i 06i	Dull-grey	R U R U W
099 128 064 090	·095	9·8	45,844	·30 ·40 ·20 ·20	·27	5·6	4·82	1i 40 8 1i		X X X X

ges 142, 143.

TABULATED RESULTS.

SECOND SERIES.

TABL

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Me
b denotes bad fracture; *r*, sligh

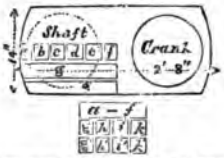
Index No.	District.	Names of the Makers or Works.	Description.	ORIGINAL Diameter.	ORIGINAL Area.	Weight on Steelyd.	Breaking Weight per square inch of Original Area.		STRET Diamete
				1.	2.	3.	4.	5.	6.
				inch.	sq. in.	lbs.	lbs.	lbs.	inch.
296	Staffordshire	MALINSLEE ♔ Best.	Rolled bars ¾ in × 1 in.	·75 × 1·00	0·7500	1247	58,661	**56,289**	·68 × ·91
297		" "		"	"	1218	57,520		·70 × ·92
298		" "		"	"	1175	55,960		·70 × ·95
299		" "		"	"	1161	55,437		·68 × ·9
300		" "		"	"	1119	53,866		·70 × ·95
701		BAGNALL ♔ J. B.	Rolled bars 1¼ in. round.	1·25	1·2271	2133	56,067	**55,000**	1·15
702		" "		"	"	2090	55,081		1·19
703		" "		"	"	2075	54,731		1·20
704		" "		"	"	2048	54,123		1·18
705		Do. Do.	Do. do. Turned down to 1 in.	1·00	0·7854	1262	56,539	**55,381**	·91
706		" "		"	"	1247	56,005		·95
707		" "		"	"	1226	55,256		·95
708		" "		"	"	1183	53,723		·96
709	Lanarkshire	◈ GOVAN ◈	Rolled bars 1¼ in. round.	1·25	1·2271	2275	59,302	**57,598**	1·19
710		" "		"	"	2232	58,321		1·18
711		" "		"	"	2161	56,701		1·18
712		" "		"	"	2133	56,067		1·17
713		Do. Do.	Do. do. Turned down to 1 in.	1·00	0·7854	1348	59,605	**57,288**	·93
714		" "		"	"	1275	57,003		·93
715		" "		"	"	1262	56,539		·94
716		" "		"	"	1247	56,005		·94
717		Do. Do.	Do. do. Forged down to 1 in.	0·99	0·7698	1291	58,740	**57,095**	·94
718		" "		"	"	1247	57,141		·94
719		" "		"	"	1233	56,500		·93
720		" "		"	"	1219	56,000		·92
721		Do. Do.	Rolled bars 1 in. round.	1·02	0·8171	1419	59,726	**58,746**	·95
722		" "		1·03	0·8333	1440	59,270		·95
723		" "		1·02	0·8171	1376	58,252		·96
724		" "		1·02	0·8171	1361	57,738		·95
725		Do. Do.	Rolled bars ⅝ in. round.	0·63	0·3116	350	60,558	**58,199**	·60
726		" "		"	"	343	59,929		·59
727		" "		"	"	308	56,784		·60
728		" "		"	"	294	55,526		·60
729		GLASGOW B. Best.	Rolled bars 1¼ in. round.	1·25	1.2271	2148	56,404	**54,579**	1·16
730		" "		"	"	2117	55,697		1·16
731		" "		"	"	2018	53,439		1·20
732		" "		"	"	1989	52,776		1·19
733		Do. Do.	Do. do. Turned down to 1 in.	1·02	0·8171	1361	57,738	**55,533**	·92
734		" "		"	"	1304	55,761		·95
735		" "		"	"	1275	54,791		·96
736		" "		"	"	1247	53,844		·93
737		Do. Do.	Do. do. Forged down to 1 in.	1·03	0·8333	1446	59,506	**56,112**	·95
738		" "		1·03	0·8333	1390	57,590		·98
739		" "		1·00	0·7854	1233	55,505		·95
740		" "		1·03	0·8333	1219	51,846		·99
741		Do. Do.	Rolled bars ⅝ in. round.	0·63	0·3116	313	59,929	**59,300**	·59
742		" "		"	"	343	59,929		·59
743		" "		"	"	339	58,671		·59
744		" "		"	"	339	58,671		·59
745		DUNDYVAN (Common).	Rolled bars 1¼ in. round.	1·25	1·2271	2246	58,640	**51,327**	1·21
746		" "		"	"	1934	51,521		1·22
747		" "		"	"	1847	49,536		1·23
748		" "		"	"	1675	45,611		1·24
749		Do. (Do.)	Do. do. Turned down to 1 in.	1·00	0·7854	1361	60,069	**55,995**	·95
750		" "		"	"	1304	58,036		·96
751		" "		"	"	1190	53,972		·98
752		" "		"	"	1132	51,905		·98

117,

cept those marked *Samples*, which were received from the Makers.
acture; *s* size at smallest part.

e between ial and ed Areas.		Breaking Wght. per sq. in. of Stretched Area.	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght. per sq. in. of Fractured Area.	ELONGATION.				FRACTURE.		
			Diameter.	Area.					Length of part stretched in Column 20.				Crys	Col.	Kind
9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
in.	℔ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	℔ ct.	lbs.	inch.	inch.	ins.	℔ ct.	℔ct.		
063	14·2	65,596	·58 × ·82 ·57 × ·77 ·61 × ·81 ·58 × ·80 ·61 × ·85	·4756 ·4389 ·4941 ·4640 ·5185	·2944 ·3111 ·2559 ·2860 ·2315	·2778	37·0	88,300	1·71 1·56 1·34 1·87 1·24	1·54	7·2	21·4	73 11 8 1 0*r*	Fine	X U U S S
332	10·9	61,700	1·03 1·03 1·20 1·00	0·8333 0·8333 1·1310 0·7854	·3938 ·3938 ·0961 ·4417	·3318	27·0	75,351	1·63 1·33 0·84 1·38	1·30	7·5	17·3	3 10 46 0	Irregular	S U X S
875	11·1	62,324	·85 ·83 ·78 ·86	·5674 ·5310 ·4779 ·5812	·2180 ·2544 ·3075 ·2042	·2460	31·3	80,638	1·47 1·38 1·63 1·25	1·43	7·5	19·1	4 22 1 7		S S X S U
335	10·9	64,630	·90 ·90 ·87 ·87	·6362 ·6362 ·5945 ·5945	·5909 ·5909 ·6326 ·6326	·6118	49·8	114,866	1·64 1·69 1·73 1·78	1·71	7·0	24·8	0 0 0 0	Light-grey; fibre uniformly fine	P P P P
980	12·5	65,455	·72 ·70 ·70 ·68	·4071 ·3848 ·3848 ·3632	·3783 ·4006 ·4006 ·4222	·4004	51·0	116,869	1·98 1·95 1·82 1·94	1·92	7·5	25·6	0 0 0 0		P P P P
936	12·1	65,070	·70 ·69 ·71 ·72	·3848 ·3739 ·3958 ·4071	·3850 ·3959 ·3740 ·3627	·3794	49·2	112,705	1·48 1·58 1·52 1·44	1·50	6·5	23·1	0 0 0 0		P P P P
086	13·2	67,708	·72 ·73 ·75 ·74	·4071 ·4184 ·4417 ·4300	·4100 ·4149 ·3754 ·3871	·3969	48·3	113,700	1·63 1·52 1·47 1·43	1·51	6·0	25·2	0 0 0 0		P P P P
312	10·0	64,675	·43 ·46 ·45 ·44	·1452 ·1662 ·1590 ·1521	·1664 ·1454 ·1526 ·1595	·1560	50·1	116,549	1·20 1·27 1·23 1·10	1·20	5·6	21·4	0 0 0 0		P P P P
379	11·2	61,496	0·88 0·94 1·07 1·10	·6082 ·6940 ·8992 ·9503	·6189 ·5331 ·3279 ·2768	·4392	35·8	85,012	1·93 1·82 1·26 1·06	1·52	7·5	20·3	0 0 4 16	Fibre close, but irregular	S S U S X
225	15·0	65,334	·70 ·76 ·89 ·90	·3848 ·4536 ·6220 ·6362	·4323 ·3635 ·1951 ·1809	·2929	35·8	86,590	2·08 1·60 1·30 1·42	1·60	7·5	21·3	0 0 5 28		S S U S X
859	10·4	62,677	·75 ·84 ·85 ·95	·4417 ·5441 ·5674 ·7088	·3916 ·2892 ·2180 ·1245	·2558	31·1	81,508	1·64 1·23 1·28 0·70	1·21	6·5	18·6	0 1 4*r* 22		S S U S X
405	13·0	68,160	·45 ·51 ·46 ·52	·1590 ·2043 ·1662 ·2124	·1526 ·1073 ·1454 ·0992	·1261	40·4	99,612	1·32 1·00 1·18 0·97	1·12	5·6	20·0	0 0 0 0		S S S S
484	4·0	53,436	1·20 1·22 1·22 1·23	1·1310 1·1690 1·1690 1·1882	·0961 ·0581 ·0581 ·0389	·0628	5·1	54,100	0·88 0·45 0·31 0·24	0·47	7·5	6·3	92 100 100 100	Coarse	Y Y Y Y
501	6·4	59,824	·88 ·96 ·95 ·97	·6082 ·7238 ·7088 ·7392	·1772 ·0616 ·0766 ·0462	·0904	11·5	63,280	1·36 0·86 0·65 0·47	0·83	7·5	11·1	68 85 45 82		V Y V Y V Y V Y

NOTE.—All the pieces were taken *promiscuously* from Engineers' or
***b* denotes bad fracture; *r*, sli**

Index No.	District.	Names of the Makers or Works.	Description.	ORIGINAL		Weight on Steelyd.	Breaking Weight per square inch of Original Area.		STRE
				Diameter.	Area.				Diamet
				1.	2.	3.	4.	5.	6.
				inch.	sq. in.	lbs.	lbs.	lbs.	inch.
753	Lanarkshire	**DUNDYVAN** (Common).	Rolled bars 1¼ in. Forged down.	1·03	0·8333	1534	62,429	**54,247**	0·94
754		" "		"	"	1333	55,675		1·00
755		" "		"	"	1190	50,870		1·01
756		" "		"	"	1105	48,014		1·02
757		Do. (Do.)	Rolled bars 1 in. round.	1·02	0·8171	1417	59,657	**53,352**	0·95
758		" "		"	"	1220	52,906		0·99
759		" "		"	"	1190	51,879		1·00
760		" "		"	"	1105	48,966		1·01
761		**BLOCHAIRN** B. Best.	Rolled bars 1 in. round.	1·00 ●	0·7854	1304	58,049	**56,141**	0·93
762		" "		"	"	1262	56,539		0·92
763		" "		"	"	1247	56,005		0·92
764		" "		"	"	1190	53,972		0·91
765		**PORT-DUNDAS** Ex. B. Best.	Rolled bars 1⅛ in. round.	1·12	0·9852	1706	57,692	**54,594**	1·04
766		" "		1·12	0·9852	1675	56,811		1·03
767		" "		1·10	0·9503	1604	56,805		1·00
768		" "		1·10	0·9503	1593	56,481		1·01
769		" "		1·12	0·9852	1618	55,191		1·05
770		" "		1·09	0·9332	1162	44,584		1·08
771		**GOVAN** Puddled Iron.	Rolled bars ½ × 2¼ Forged down.	0·92	0·6650	990	55,323	**46,771**	0·91
772		" "		0·93	0·6808	961	52,847		0·91
773		" "		0·92	0·6650	763	45,765		0·92
774		" "		0·96	0·7238	533	33,150		0·96
775	So. Wales	**YSTALYFERA** Puddled Iron.	Rolled bars ¾ × 2¼ Forged down.	1·22	1·1690	13[illegible]4	39,000	**29,626**	1·22
776		" "		1·20	1·1310	961	31,812		1·20
777		" "		1·21	1·1499	792	27,173		1·21
778		" "		1·20	1·1310	505	20,521		1·20
779		Do. Do.	Do. do. Strips cut off.	·70 × 1·02	0·7140	721	40,977	**38,526**	·69×1·0
780		" "		"	"	647	38,075		·70×1·0
781		" "		"	"	647	38,075		·70×1·0
782		" "		"	"	619	36,979		·69×1·0
783	*a* Lengthways	Cut out of a CRANK-SHAFT of Hammered Scrap Iron, thus—  and reduced to the required shape in the lathe, not on the anvil.		1·00	0·7854	926	44,561	**43,759**	·94
784	*b*			"	"	919	44,311		·92
785	*c*			"	"	894	43,420		·97
786	*d*			"	"	894	43,420		·95
787	*e*			"	"	894	43,420		·95
788	*f*			"	"	894	43,420		·92
789	*g* Crossways			1·01	0·8012	8[illegible]4	40,467	**38,487**	·97
790	*h*			1·02	0·8171	847	40,124		·97
791	*i*			1·00	0·7854	819	40,745		·95
792	*k*			1·02	0·8171	761	37,177		·98
793	*g′*			1·01	0·8012	792	39,000		·99
794	*h′*			1·02	0·8171	847	40,124		·99
795	*i′*			1·00	0·7854	733	37,680		·99
796	*k′*			1·00	0·7854	590	32,582		·99
797	Crossways	HAMMERED ARMOUR-PLATE 16 ,, 6×3 ,, 9×4½ ins. cut off the end and turned down.		1·00	0·7854	819	40,745	**38,868**	·95
798				"	"	776	39,213		·95
799				"	"	704	36,646		·96
800		Do. Do.		1·00	0·7854	776	39,213	**36,821**	·98
801		" "		"	"	704	36,616		·97
802		" "		"	"	647	34,614		·99
803	Foreign	SWEDISH, OC	4 Flat Tilted Bars. Strips cut off.	·50 × 0·66	0·3300	253	48,933		·47×0·6
804		" " ♔ ♔ W.		·64 × 0·92	0·5888	591	43,509		·58×0·8
805		" " ♔ C.		·60 × 1·10	0·6600	676	42,421		·57×1·0
806		RUSSIAN, IO P 3.		·59 × 1·17	0·6903	1133	59,096		·58×1·1
807		SWEDISH, OC	Forged round.	·62	0·3019	218	50,[illegible]62		·59
808		" " ♔ C.		·85	0·5674	512	41,251		·80
809		" " ♔ ♔ W.		·73	0·4184	337	44,230		·67
810		RUSSIAN, IO P 3.		·85	0·5674	719	51,466		·81

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, except those marked *Samples*, which were received from the Makers.
at fracture; *s* size at smallest part.

rence between riginal and etched Areas.		Breaking Wght. per sq. in. of Stretched Area.	FRACTURED		Difference between Original and Fractured Areas.			Breaking Wght. per sq. in of Fractured Area.	ELONGATION. Length of part stretched in Column 20.				FRACTURE.		
			Diameter.	Area.									Crys	Col.	Kind
9.	10.	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.
sq. in.	℔ ct.	lbs.	inch.	sq. in.	sq. in.	sq. in.	℔ ct.	lbs.	inch.	inch.	ins.	℔ ct.	℔ct.		
·0589	7·5	58,372	0·85	·5674	·2659	·0905	10·8	60,856	1·26	0·55	7·5	7·3	40	Coarse and irregular.	Y Y
			1·00	·7854	·0479				0·50				65		Y Y
			1·01	·8012	·0321				0·33				97		Y
			1·02	·8171	·0162				0·12				100		Y
·0508	6·2	56,889	0·93	·6808	·1363	·0694	8·5	58,304	1·17	0·46	6·8	6·8	68		Y Y
			0·97	·7392	·0779				0·32				100		Y
			1·00	·7854	·0317				0·20				100		Y
			1·00	·7854	·0317				0·16				96		Y
·1201	15·3	66,272	0·85	·5674	·2180	·2972	37·8	90,313	1·22	1·45	6·8	21·3	12*r*	Fine and uniform except 770.	U
			0·77	·4657	·3197				1·53				1		S
			0·78	·4779	·3075				1·44				0		S
			0·75	·4417	·3437				1·60				1		S
·1230	12·7	62,645	0·87	·5945	·3907	3484	36·1	85,563	1·74	1·44	7·0	20·6	0		S
			0·85	·5674	·4178				1·76				0		S
			0·85	·5674	·3829				1·71				0		S
			0·82	·5281	·4222				1·62				3		S
			0·88	·6082	·3770				1·50				0		S
			1·03	·8333	·0999				0·32				48		S X
·0112	1·6	47,292	0·90*s*	·6362	·0288	·0219	3·2	48,057	0·37	0·24	7·0	3·4	85	Coarse, open, and very irregular.	b
			0·89	·6220	·0588				0·44				*r*40*r*		b
			0·92	·6650	·0000				0·11				93		b
			0·96	·7238	·0000				0·03				95*b*		**b**
·0000	0·0	29,626	1·21	1·1499	·0191	·0048	0·0	29,818	0·10	0·04	7·0	0·6	94		b
			1·20	1·1310	·0000				0·05				94		b
			1·21	1·1499	·0000				0·02				85*b*		b
			1·20	1·1310	·0000				0·00				55*b*		b
·0085	1·2	38,996	·68 × 1·00	·6800	·0340	·0170	2·4	39,470	0·25	8·14	7·0	2·0	82		**a**
			·70 × 1·02	·7140	·0000				0·08				70		a
			·70 × 1·02	·7140	·0000				0·06				100		a
			·68 × 1·00	·6800	·0340				0·18				44		a
·0886	11·3	49,323	·88	·6082	·1772	·1814	23·1	56,910	1·14	1·33	6·5	20·5	78	Whitish-grey and lustrous—uniform, varied;	c
			·87	·5945	·1909				1·34				22		c
			·90	·6362	·1492				1·06				50*r*		c
			·85	·5674	·2180				1·53				36		c
			·90	·6362	·1492				1·30				53*r*		c
			·85	·5812	·2042				1·60				28		**c**
·0487	6·1	40,991	·95	·7088	·0924	·0678	8·5	42,059	0·98	0·67	8·0	8·4	18		e
			·96	·7238	·0933				0·92				55		e
			·95	·7088	·0766				0·98				3		e
			·97	·7392	·0779				0·79				30		c e
			·99	·7698	·0324				0·46				68		c
			·97	·7392	·0779				0·66				60		**d**
			·95	·7088	·0766				0·40				0*r*		**e**
			·99	·7698	·0156				0·20				50*b*		
-0716	9·1	42,767	·92	·6650	·1204	·1011	12·8	44,611	1·16	0·94	8·0	11·7	5	Laminated fibrous.	**f**
			·94	·6940	·0914				0·92				8		f
			·94	·6940	·0914				0·75				4*r*		f
·0310	3·9	38,298	·97	·7392	·0462	·0462	5·9	39,085	0·60	0·51	8·0	6·4	1		f
			·97	·7392	·0462				0·55				4		f
			·97	·7392	·0462				0·38				0		f
	13·1	56,345	·30 × 0·38	·1140	·2160		65·5	141,702	1·34		8·0	17·0	0	Very fine, but varied.	K
	16·3	51,964	·46 × 0·72	·3312	·2576		43·7	77,349	1·18		7·7	15·3	0		K
	11·9	48,156	·50 × 0·88	·4400	·2200		33·3	63,632	1·02		6·7	15·2	0		K
	8·4	61,160	·55 × 1·09	·5995	0908		13·1	68,047	0·49		8·2	6·0	55*r*		K Z
	9·4	55,501	·32	·0804	2215		73·3	188,731	1·42		7·6	18·7	0		K
	11·4	46,574	·55	·2376	·3298		58·1	98,510	1·18		8·0	14·8	0		K
	15·7	52,484	·53	·2207	·1977		47·2	83,851	1·20		7·6	15·8	0		K
	9·2	56,670	·74	·4300	·1374		24·2	67,907	0·60		8·0	7·5	2		K Z

TABL

Note.—All the pieces were taken *promiscuously* from Engineers' or M

L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture;

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL. Thick. Bdth. 1. 2. inch inch.	ORIGINAL. Area. 3. sq. in.	Weight on Steelyd. 4. lbs.	Breaking Weight per square inch of Original Area. 5. lbs.	6. lbs.	7. lbs.	FRAC Thick. Bd 8. 9 inch. in
551	Lanarkshire	GLASGOW,	L	·650 × 1·52	0·988	1389	48,544			·625 × 1
552		Best Best.	,,	·640 × 1·52	0·973	1361	48,487			·605 × 1
553		,, ,,	,,	·500 × 2·00	1·000	1403	48,354			·475 × 1
554		,, ,,	,,	·555 × 2·00	1·110	1576	47,926			·530 × 1
555		,, ,,	,,	·480 × 2·00	0·960	1304	47,480			·450 × 1
556		,, ,,	,,	·550 × 2·00	1·100	1518	46,885	45,626		·525 × 1
557		,, ,,	,,	·645 × 1·55	1·000	1276	44,798			·612 × 1
558		,, ,,	,,	·500 × 1·62	0·810	961	44,417			·495 × 1
559		,, ,,	,,	·430 × 2·00	0·860	1019	43,723			·400 × 1
560		,, ,,	,,	·455 × 2·00	0·910	1063	42,670			·425 × 1
561		,, ,,	,,	·665 × 1·62	1·077	1161	38,605		43,483	·655 × 1
562		Do. Do.	C	·555 × 2·00	1·110	1475	45,379			·535 × 1
563		,, ,,	,,	·555 × 2·00	1·110	1475	45,379			·542 × 1
564		,, ,,	,,	·650 × 1·55	1·008	1305	45,248			·625 × 1
565		,, ,,	,,	·650 × 1·52	0·988	1189	42,876			·630 × 1
566		,, ,,	,,	·500 × 2·00	1·000	1133	40,794			·500 × 2
567		,, ,,	,,	·500 × 2·00	1·000	1104	39,982	41,340		·500 × 2
568		,, ,,	,,	·450 × 2·00	0·900	961	39,975			·450 × 2
569		,, ,,	,,	·650 × 1·52	0·988	1075	39,646			·630 × 1
570		,, ,,	,,	·450 × 2·00	0·900	932	39,073			·440 ×
571		,, ,,	,,	·500 × 1·62	0·810	790	38,506			·497 ×
572		,, ,,	,,	·665 × 1·62	1·077	1133	37,878			·665 ×
573		GLASGOW,	L	·500 × 1·55	0·775	1276	57,804			·462 ×
574		Best Best.	,,	·800 × 1·38	1·104	1917	56,835			·705 ×
575		,, ,,	,,	·625 × 2·00	1·250	2197	56,464			·570 ×
576		,, ,,	,,	·265 × 2·00	0·530	733	55,838			·244 ×
577		,, ,,	,,	·785 × 1·38	1·083	1818	55,377			·685 ×
578		,, ,,	,,	·875 × 1·50	1·312	2247	54,868			·806 ×
579		,, ,,	,,	·485 × 2·00	0·970	1561	54,410			·450 ×
580		,, ,,	,,	·550 × 2·00	1·100	1775	53,427			·505 ×
581		,, ,,	,,	·480 × 2·00	0·960	1504	53,314			·445 ×
582		,, ,,	,,	·265 × 2·00	0·530	683	53,196	53,399		·244 ×
583		,, ,,	,,	·625 × 1·55	0·969	1504	52,819			·595 ×
584		,, ,,	,,	·625 × 2·00	1·250	2018	52,432			·570 ×
585		,, ,,	,,	650 × 1·52	0·988	2519	52,229			·600 ×
586		,, ,,	,,	·775 × 1·55	1·201	1902	51,895			·700 ×
587		,, ,,	,,	·650 × 1·52	0·988	1501	51,803			·606 ×
588		,, ,,	,,	·562 × 2·00	1·124	1733	51,240			·521 ×
589		,, ,,	,,	·885 × 1·50	1·327	2075	50,618			·834 ×
590		,, ,,	,,	·550 × 2·00	1·100	1504	46,528		47,595	·524 ×
591		Do. Do.	C	·880 × 1·50	1·320	1990	49,083			·844 ×
592		,, ,,	,,	·785 × 1·38	1·083	1447	45,786			·728 ×
593		,, ,,	,,	·890 × 1·50	1·335	1789	44,317			·872 ×
594		,, ,,	,,	·480 × 2·00	0·960	1133	42,490			·475 ×
595		,, ,,	,,	·265 × 2·00	0·530	476	42,260			·258 ×
596		,, ,,	,,	·485 × 2·00	0·970	1133	42,056			·480 ×
597		,, ,,	,,	·650 × 1·55	1·008	1190	42,053	41,791		·639 ×
598		,, ,,	,,	·775 × 1·55	1·201	1447	41,287			·750 ×
599		,, ,,	,,	·500 × 1·55	0·775	819	41,164			·456 ×
600		,, ,,	,,	·625 × 2·00	1·250	1447	39,664			·610 ×
851		,, ,,	,,	·570 × 2·00	1·140	1276	39,297			·562 ×
852		,, ,,	,,	·550 × 2·00	1·100	1219	39,202			·542 ×
853		,, ,,	,,	·645 × 1·52	0·980	1047	39,170			·628 ×
854		,, ,,	,,	·650 × 1·52	0·988	990	37,237			·635 ×
855		GLASGOW,	L	·650 × 1·55	1·008	1604	53,553			·575 × 1
856		Best Scrap.	,,	·650 × 1·55	1·008	1533	51,581	50,844		·600 × 1
857		,, ,,	,,	·625 × 1·55	0·969	1447	51,172			·570 × 1
858		,, ,,	,,	·625 × 1·55	0·969	1305	47,069			·555 × 1
859		MALINSLEE, Best.	L	·385 × 1·55	0·793	1168	52,679	52,572		·350 × 1
860		,, 𝔗 ,,	,,	·385 × 1·55	0·793	1162	52,466		51,600	·355 × 1
861		Do. Do.	C	·390 × 1·55	0·803	1219	53,801	50,627		·366 × 2
862		,, ,,	,,	·385 × 1·55	0·793	1020	47,453			·355 × 2

ge 127.

xcept those marked *Samples*, which were received from the Makers.
part; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

Difference between ractured and Original Areas.				Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
												Crys.	Col.	Kind.
12. sq. in.	13. sq. in.	14. ₰ ct.	15. ₰ ct.	16. lbs.	17. lbs.	18. inch.	19. inch.	20. inch	21. inch	22. ₰ ct.	23. ₰ ct.	24. ₰ ct.	25.	26.
·052	·037	5·3	3·8	48,208	45,319	·35	·33	·255	7·6	4·34	3·35	50	Dull-gray; fibre and crystals coarse	W T
						·40						45		W T
						·33						54		W T
						·39						55		W T
						·34						18*i*		W
						·40						45		W T
						·40						70		W T
						·28						60*i*		W T
						·35						14*i*		W
						·31						10*i*		W
						·07						35*bi*		W T
·022		2·2		42,430		·26	·18			2·37		55		W T
						·22						48		W T
						·28						63		W T
						·21						38		W T
						·13						25*i*		W
						·05						16*i*		W
						·17						18*i*		W
						·22						40		W T
						·23						10*i*		W
						·14						8		W
						·07						20*ii*		W
·109	·074	10·6	7·2	59,557	51,585	·78	·68	·440	7·6	8·95	5·79	75	Gray; fibre and crystals rather coarse and irregular	R
						·88						53		R
						·96						55		R
						·60						32		R U
						·70						94		R
						·62						92		R
						·72						56		R
						·67						22		R U
						·68						50		R
						·62						25		R U
						·65						55*i*		R
						·84						48		R
						·80						20		R U
						·68						90		R
						·65						38*i*		R
						·43						10		R U
						·52						86		R
						·42						25		R U
·039		3·7		43,614		·33	·20			2·63		90		T
						·43						12		W U
						·21						55		W T
						·17						22		W T
						·12						10		W T
						·15						35		W T
						·11						15		W
						·20						52		W T
						·18						15		W
						·20						5		W
						·18						4		W
						·18						8		W
						·17						10		W
						·10						12		W
·128		13·0		58,412		·99	·80		7·6	10·5		55	Gray; fine	R
						·72						12		W R
						·82						20*i*		U
						·67						6		U
·122	·098	15·4	12·4	62,131	58,939	·57	·65	·545	7·6	8·6	7·20	32		R U
						·73						3*i*		U
·074		9·3		55,746		·53	·44			5·8		10		V
						·35						35		S Y

NOTE.—All the pieces were taken *promiscuously* from Engineers' or
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture;

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL. Thick. Bdth. 1. 2. inch inch.	ORIGINAL. Area. 3. sq. in.	Weight on Steelyd. 4. lbs.	Breaking Weight per square inch of Original Area. 5. lbs.	6. lbs.	7. lbs.	FRAC Thick. 8. inch.
863	Durham	CONSETT,	L	·630 × 1·66	1·047	1761	55,758			·575 ×
864		Best Best.	"	·587 × 1·75	1·027	1672	54,416			·550 ×
865		" "	"	·637 × 1·50	0·955	1511	53,799			·600 ×
866		" "	"	·650 × 1·66	1·080	1733	53,328			·604 ×
867		" "	"	·420 × 1·77	0·743	1084	53,058			·375 ×
868		" "	"	·550 × 1·77	0·976	1504	52,441			·505 ×
869		" "	"	·625 × 1·77	1·106	1733	52,074			·570 ×
870		" "	"	·550 × 1·77	0·976	1475	51,609			·509 ×
871		" "	"	·435 × 1·75	0·761	1076	51,509			·390 ×
872		" "	"	·887 × 1·38	1·224	1901	50,943			·822 ×
873		" "	"	·470 × 1·75	0·822	1163	50,650			·420 ×
874		" "	"	·750 × 1·51	1·132	1704	50,160			·672 ×
875		" "	"	·637 × 1·66	1·057	1505	48 450	49,120		·580 ×
876		" "	"	·470 × 1·75	0·822	1090	48,163			·422 ×
877		" "	"	·567 × 1·77	1·006	1392	47,759			·526 ×
878		" "	"	·470 × 1·75	0·822	1076	47,686			·410 ×
879		" "	"	·560 × 1·77	0·994	1361	47,372			·528 ×
880		" "	"	·450 × 1·77	0·796	1019	47,239			·410 ×
881		" "	"	·755 × 1·38	1·042	1419	46,835			·700 ×
882		" "	"	·637 × 1·66	1·057	1391	45,429			·576 ×
883		" "	"	·437 × 2·01	0·878	1047	43,720			·395 ×
884		" "	"	·450 × 2·01	0·904	1076	43,360			·430 ×
885		" "	"	·437 × 2·01	0·878	990	41,902			·400 ×
886		" "	"	·450 × 2·01	0·904	1004	41,130		47,938	·425 ×
887		Do. Do.	C	·587 × 1·75	1·027	1633	53,353			·575 ×
888		" "	"	·887 × 1·38	1·224	1932	51,606			·813 ×
889		" "	"	·450 × 2·01	0·904	1334	51,352			·440 ×
890		" "	"	·637 × 1·50	0·955	1391	50,280			·625 ×
891		" "	"	·420 × 1·77	0·743	1004	50,043			·400 ×
892		" "	"	·755 × 1·38	1·042	1533	49,900			·695 ×
893		" "	"	·637 × 1·66	1·059	1560	49,811			·602 ×
894		" "	"	·560 × 1·77	0·994	1361	47,372			·535 ×
895		" "	"	·435 × 1·75	0·761	962	47,314			·420 ×
896		" "	"	·637 × 1·66	1·059	1447	46,823			·615 ×
897		" "	"	·625 × 1·77	1·106	1505	46,302			·596 ×
898		" "	"	·450 × 1·77	0·796	990	46,206	46,755		·426 ×
899		" "	"	·567 × 1·77	1·006	1333	46,117			·545 ×
900		" "	"	·595 × 1·66	0·989	1304	46,089			·570 ×
901		" "	"	·450 × 2·01	0·904	1161	45,993			·440 ×
902		" "	"	·437 × 2·01	0·878	1104	45,538			·420 ×
903		" "	"	·637 × 1·66	1·057	1362	44,660			·603 ×
904		" "	"	·550 × 1·77	0·976	1219	44,266			·528 ×
905		" "	"	·550 × 1·77	0·976	1219	44,266			·525 ×
906		" "	"	·437 × 2·01	0·878	1060	44,134			·419 ×
907		" "	"	·637 × 1·66	1·057	1334	43 919			·609 ×
908		" "	"	·470 × 1·75	0·822	962	43,803			·448 ×
909		" "	"	·470 × 1·75	0·822	912	42,100			·452 ×
910		" "	"	·470 × 1·75	0·822	876	40,873			·452 ×
911		CONSETT,	L	·420 × 1·55	·651	1019	57,760			·372 ×
912		Best Best.	"	·450 × 1·57	·706	1104	56,631			·412 ×
913		" "	"	·437 × 1·57	·686	1058	56,405			·383 ×
914		" "	"	·420 × 1·55	·651	933	54 061			·370 ×
915		" "	"	·570 × 1·57	·895	1392	53,683			·508 ×
916		" "	"	·440 × 1·57	·691	976	52,675	53,559		·400 ×
917		" "	"	·425 × 1·55	·659	904	52,173			·378 ×
918		" "	"	·590 × 1·57	·926	1376	51 402			·525 ×
919		" "	"	·590 × 1·57	·926	1361	50,948			·525 ×
920		" "	"	·450 × 1·57	·706	933	49,850		49,618	·420 ×
921		Do. Do.	C	·420 × 1·55	·651	847	50,362			·408 ×
922		" "	"	·430 × 1·57	·675	876	49,775			·410 ×
923		" "	"	·450 × 1·57	·706	862	47,034			·434 ×
924		" "	"	·575 × 1·57	·903	1161	46,044			·514 ×
925		" "	"	·590 × 1·57	·926	1190	45,775			·568 ×
926		" "	"	·450 × 1·56	·702	820	45,612	45,677		·430 ×
927		" "	"	·570 × 1·57	·895	1118	45,111			·552 ×
928		" "	"	·420 × 1·55	·651	705	44,255			·400 ×
929		" "	"	·437 × 1·57	·686	705	41,997			·418 ×
930		" "	"	·450 × 1·57	·706	705	40,807			·436 ×

e 137.

xcept those marked *Samples*, which were received from the Makers.
part; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

Difference between ractured and Original Areas.				Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
												Crys.	Col.	Kind.
12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
q. in.	sq. in.	⅌ ct.	⅌ ct.	lbs.	lbs.	inch.	inch.	inch	inch.	⅌ ct.	⅌ ct.	⅌ ct.		
						·72						40	Colour, dullish gray, generally uniform; fibre and crystals generally close and fine	R U
						·53						32		R U
						·41						50		R U
						·47						45		R U
						·60						18		U
						·68						42*i*		R U
						·74						18		U
						·60						10		U
						·60						11*i*		U
						·60						20		R U
						·58						4		U
						·56						45		R U
·108		11·3		55,472		·65	·53			8·0		22		R U
						·40						22		R U
						·50						1		U
						·55						0		U
						·47						4		U
						·43						0		U
						·50						18		U
						·60						3		U
						·41						1		U
						·37						0*i*		U
						·30						0		U
						·44						0*ii*		U
	·084		8·8		52,736			435	6 6		6·60			
						·32						38		R V
						·53						5		V
						·30						30		R V
						·31						44		R V
						·30						50		R V
						·56						45		R V
						·33						35		R V
						·35						5		V
						·26						3		V
						·30						20		V
						·32						12		V
						·28						2		V
·060		6·3		50,000		·30	·34			5·2		1		V
						·32						1		V
						·30						2		V
						·31						8*i*		V
						·40						18		V
						·28						15*i*		V
						·46						1		V
						·33						8		V
						·43						12		V
						·37						2		V
						·20						1*i*		V
						·20						4*i*		V
						·32						35		R U
						·36						48		R U
						·50						10		U
						·37						2		U
						·44						22		U
·108		14·4		62,346		·43	·38			11·5		5		U
						·35						2		U
						·43						5		U
						·38						7		U
						·22						11		U
	·075		10·0		55,352			·255	3·3		7·75			
						·08						18		V
						·15						4		V
						·13						5		V
						·20						7		V
						·18						3		V
·042		5·6		48,358		·14	·13			4·0		7		V
						·10						12		V
						·12						1		V
						·11						1*i*		V
						·12						2*i*		V

Note.—All the pieces were taken *promiscuously* from Engineers' or
L denotes that the strain was applied *lengthways* of the plate; C, *crossways*; *f*, size at fracture

Index No.	District.	Names of the Makers or Works.	See Note.	ORIGINAL.			Weight on Steelyd.	Breaking Weight per square inch of Original Area.			FRAC
				Thick.	Bdth.	Area.					Thick.
				1.	2.	3.	4.	5.	6.	7.	8.
				inch	inch.	sq. in.	lbs.	lbs.	lbs.	lbs.	inch.
931	Shropshire	Snedshill, ♕ Best.	L	·345 ×	2·06	·711	1104	56 233	52,362	47,699	·305 × 1
932		" "	"	·470 ×	"	·968	1589	55,332			·426 × 2
933		" "	"	·400 ×	"	·824	1263	53,525			·330 × 1
934		" "	"	·395 ×	"	·814	1090	48,636			·355 × 1
935		" "	"	·440 ×	"	·906	1219	47,684			·400 × 2
936		Do. Do.	C	·345 ×	"	·711	876	47,255	43,036		·378 × 2
937		" "	"	·395 ×	"	·814	948	43,752			·378 × 2
938		" "	"	·470 ×	"	·968	1162	42,980			·455 × 2
939		" "	"	·445 ×	"	·917	1061	42,288			·426 × 2
940		" "	"	·400 ×	"	·824	821	38,905			·380 × 2
941	Staffordshire	G.B. Thorneycroft, Best D W Best.	L	·915 ×	1·50	1·372	2424	56,080	54,847	50,216	·845 × 1
942			"	·930 ×	1·38	1·283	2240	55,954			·850 × 1
943		" "	"	·930 ×	1·38	1·283	2082	52,507			·820 × 1
914		Do. Do.	C	·930 ×	1·38	1·283	1818	46,745	45,585		·890 × 1
945		" "	"	·900 ×	1·50	1·350	1818	44,425			·875 × 1
946		J. Wells ♕ B. Best.	L	·650 ×	1·55	1·007	1547	52,021	45,997	47,654	·605 × 1
947		" " *Sample Plates*	"	·650 ×	1·51	0·981	1391	48,948			·602 × 1
948		" "	"	·637 ×	1·50	0·955	1334	48,610			·575 × 1
949		" "	"	·750 ×	1·54	1·155	1505	44,238			·695 × 1
950		" "	"	·637 ×	1·50	0·955	1104	41,866			·575 × 1
951		" "	"	·750 ×	1·54	1·155	1334	40,192			·716 × 1
952		Do. Do.	C	·637 ×	1·52	0·968	1475	52,035	49,311		·570 × 1
953		" "	"	·650 ×	1·52	0·988	1447	50,189			·612 × 1
954		" "	"	·650 ×	1·50	0·975	1419	50,053			·602 × 1
955		" "	"	·637 ×	1·50	0·955	1376	49,841			·580 × 1
956		" "	"	·750 ×	1·55	1·162	1733	49,565			·695 × 1
957		" "	"	·750 ×	1·52	1·140	1475	44,184			·720 × 1
958		Lloyds, Foster, & Co. " Best. "	L	·355 ×	2·06	·731	919	47,609	44,967	44,850	·325 ×
959			"	·373 ×	"	·768	935	45,908			·330 ×
960		" "	"	·440 ×	"	·906	1133	45,026			·418 ×
961		" "	"	·445 ×	"	·917	1104	43,601			·420 ×
962		" "	"	·373 ×	"	·768	847	42,690			·350 ×
963		Do. Do.	C	·373 ×	"	·768	990	47,903	44,732		·350 ×
964		" "	"	·445 ×	"	·917	1219	47,113			·425 ×
965		" "	"	·373 ×	"	·768	961	46,846			·345 ×
966		" "	"	·440 ×	"	·906	1180	46,789			·420 ×
967		" "	"	·355 ×	"	·731	590	35,007			·333 ×
968	Lanarkshire	◈ Govan ◈	L	·415 ×	1·99	·826	1377	57,659	54,644	52,022	·352 ×
969		" "	"	·408 ×	"	·812	1318	57,653			·350 ×
970		" "	"	·400 ×	"	·796	1263	55,822			·350 ×
971		" "	"	·415 ×	"	·826	1210	53,014			·365 ×
972		" "	"	·400 ×	"	·796	1176	52,761			·350 ×
973		" "	"	·410 ×	"	·816	1161	50,953			·375 ×
974		Do. Do.	C	·415 ×	"	·826	1219	52,303	49,399		·380 ×
975		" "	"	·415 ×	"	·826	1219	52,303			·384 ×
976		" "	"	·415 ×	"	·826	1133	49,387			·384 ×
977		" "	"	·410 ×	"	·816	1104	49,000			·400 ×
978		" "	"	·400 ×	"	·796	1020	47,274			·384 ×
979		" "	"	·410 ×	"	·816	1020	46,127			·400 ×

N PLATES.

e 139.

xcept those marked *Samples*, which were received from the Makers.
part; *m*, mean size; *i* denotes that the layers are rather imperfectly welded; *b*, bad fracture.

Difference between actured and Original Areas.				Breaking Weight per square inch of Fractured Area.		ELONGATION. Original Length of Stretched Part in Column 21.						FRACTURE.		
												Crys.	Col.	Kind.
12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
in.	sq. in.	₱ ct.	₱ ct.	lbs.	lbs.	inch.	inch.	inch.	inch.	₱ ct.	₱ ct.	₱ ct.		
127	·086	15·0	10·2	61,581	53,441	·86	·73	·47	7·6	9·6	6·20	0	Dullish grey, generally fine	N
						·70						43		N S
						1·10						3		N
						·60						4		N
						·38						2i		N
045		5·3		45,300		·28	·21			2·8		12		N V
						·23						15		N V
						·17						58		S V
						·15						28		S V
						·23						10ii		V
164	·112	12·5	8·6	62,747	55,230	·79	·85	·60	7·6	11·2	7·90	40		N S
						·80						48		N S
						·98						65		N S
060		4·6		47,712		·42	·35			4·6		45		S V
						·28						25i		S V
108	·108	10·4	10·5	51,140	52,991	·51	·44	·45	6·6	6·7	6·85	28	Dull grey, generally rather coarse	S U
						·53						2		U
						·51						0		U
						·48						1		U
						·38						0bi		U
						·26						2		U
108		10·5		54,942		·58	·46			7·0		1		V
						·43						3		V
						·48						3		V
						·50						1		V
						·49						2		V
						·30						1i		V
071	·064	8·7	7·8	49,162	48,753	·57	·40	·375	7·6	5·3	4·95	2		U
						·52						2		U
						·26						35		S U
						·33						22		S U
						·32						22		S U
·057		6·9		48,344		·40	·35			4·6		8		V
						·34						55		S V
						·40						3		V
						·36						43		S V
						·24						2ii		V
·147	·108	18·1	13·3	66,728	60,374	·82	·77	·60	6·6	11·6	9·05	0	Light grey, very fine	M
						·82						0		M
						·91						0		M
						·82						0		M
						·76						0		M
						·50						0		M
·069		8·5		54,020		·51	·43			6·5		0		O
						·45						0		O
						·50						0		O
						·37						0		O
						·33						0		O
						·37						2		O

TAB

Note.—All the pieces were taken *promiscuously* from Engineers'
l denotes that the layers are rather imperfe

Index No.	District.	Names of the Makers or Works.	ORIGINAL.			Weight on Steelyd.	Breaking Weight per square Inch of Original Area.		FRA
			Thick.	Bdth.	Area.				Thick.
			1.	2.	3.	4.	5.	6.	8.
			Inch.	Inch.	sq. In.	lbs.	lbs.	lbs.	inch.
626	Lanarkshire	Glasgow Best Scrap	·625 *m*	1·54	0·963	1683	58,353	56,094	·520 *m*
627		" "	·620 *m*	1·54	0·955	1618	56,936		·500 *m*
628		" "	·655 *m*	1·59	1·041	1790	56,860		·575 *m*
629		" "	·655 *m*	1·54	1·009	1704	56,275		·545 *m*
630		" "	·655 *m*	1·59	1·041	1704	54,546		·550 *m*
631		" "	·620 *m*	1.54	0·955	1505	53,594		·550 *m*
632		Glasgow Best Best	·600 *m*	1·54	·924	1561	57,119	55,937	·575 *m*
633		" "	·600 *m*	1·54	·924	1547	56,695		·501 *m*
634		" "	·600 *m*	1·54	·924	1490	54,967		·500 *m*
635		" "	·600 *m*	1·54	·924	1490	54,967		·499 *m*
636		Do. Do.	·640 *m*	1·56	·998	1791	59,336	55,520	·550 *m*
637		" "	·649 *m*	1·54	·999	1743	57,932		·595 *m*
638		" "	·640 *m*	1·54	·986	1561	53,527		·595 *m*
639		" "	·640 *m*	1·56	·998	1504	51,284		·605 *m*
640		Do. Do.	·582 *m*	1·54	·896	1504	57,123	53,300	·510 *m*
641		" "	·575 *m*	1·54	·885	1461	56,472		·493 *m*
642		" "	·575 *m*	1·56	·897	1361	52,595		·495 *m*
643		" "	·575 *m*	1·54	·885	1162	47,012		·510 *m*
644		Do. Do.	·640 *m*	1·56	·998	1547	52,491	51,800	·550 *m*
645		" "	·640 *m*	1·54	·986	1518	52,306		·551 *m*
946		" "	·640 *m*	1·54	·986	1490	51,511		·500 *m*
647		" "	·640 *m*	1.56	·998	1490	50,892		·550 *m*
648	Staffordshire	Albion ⚜ Best.	·625 *m*	1·54	·963	1668	57,917	56,157	·525 *m*
649		" "	·605 *m*	1·59	·962	1617	56,492		·530 *m*
650		" "	·600 *m*	1·59	·954	1518	54,061		·530 *m*
651		Albion Best.	·650 *m*	1·54	1·001	1547	52,333	52,159	·530 *m*
652		" "	·605 *m*	1·54	0·932	1419	52,363		·520 *m*
653		" "	·582 *m*	1·54	0·896	1333	51,780		·495 *m*
654		Albion Best.	·675 *m*	1·56	1·053	1662	52,807	51,467	·600 *m*
655		" "	·675 *m*	1·54	1·039	1589	51,551		·590 *m*
656		" "	·630 *m*	1·56	0·983	1433	50,044		·605 *m*
657		Eagle Best Best.	·625 *m*	1·59	0·994	1683	56,534	54,727	·495 *m*
658		" "	·645 *m*	1·59	1·025	1662	54,250		·538 *m*
659		" "	·650 *m*	1·59	1·033	1646	53,396		·570 *m*
660		Eagle.	·650 *m*	1·54	1·001	1547	52,333	50,056	·570 *m*
661		"	·625 *m*	1·59	0·994	1504	51,491		·550 *m*
662		"	·650 *m*	1·59	1·033	1390	46,457		·580 *m*
663	Durham	Consett Best Best.	·510 *m*	1·47	·749	1177	56,109	53,548	·460 *m*
664		" "	·505 *m*	"	·742	1104	53,884		·455 *m*
665		" "	·490 *m*	"	·720	1047	53,314		·425 *m*
666		" "	·490 *m*	"	·720	1047	53,314		·425 *m*
667		" "	·510 *m*	"	·749	1076	52,334		·438 *m*
668		" "	·510 *m*	"	·749	1076	52,334		·438 *m*
669	York	Farnley.	·595 *m*	1·00	·595	1030	63,715	61,260	·450 *m*
670		"	·585 *m*	"	·585	990	62,888		·450 *m*
671		"	·595 *m*	"	·595	944	59,667		·420 *m*
672		"	·585 *m*	"	·585	904	58,772		·425 *m*

E-IRON.

9.

t those marked *Samples*, which were received from the Makers.
e: *s*, size at smallest part; *m*, mean thickness.

ence between ed and Original Areas.		Breaking Weight per square inch of Fractured Area.	ELONGATION. Original Length of Stretched Part in Column 21.				FRACTURE.		
							Crys.	Col.	Kind.
12.	14.	16.	18.	19.	21.	22.	24.	25.	26.
in.	℘ cent.	lbs.	inch.	inch.	inch.	℘ ct.	℘ ct.		
200	**20·1**	**71,764**	1·20 1·10 1·10 1·42 1·10 0·93	**1·14**	**7·6**	**15·0**	44 38 56 25 50*i* 50*i*	Close and fine	u u u **u** u u
193	**20·9**	**70,706**	0·73 1·30 1·46 1·18	**1·17**	**7·6**	**15·4**	86 45*i* 30*i* 12		v u u t
109	**11·0**	**62,373**	1·30 0·57 0·40 0·32	**0·65**	**7·6**	**8·5**	35 46 55 76*i*	Fine, but varied	u u v u v v
169	**18·9**	**65,770**	1·10 1·26 0·98 0·55	**0·97**	**7·6**	**12·8**	45 16 8*i* 5*ii*		t u t t t
201	**20·3**	**64,962**	1·05 0·87 1·00 0·93	**0·96**	**7·6**	**12·7**	40 45 22 32		t u t u t u t u
183	**19·1**	**69,367**	1·26 0·90 1·03	**1·06**	**7·6**	**14·0**	2 38*i* 55	Generally fine, but varied	t t u t u
215	**22·8**	**67,695**	1·25 1·10 0·86	**1·07**	**7·6**	**14·1**	1 28 0		**t** t v t
155	**15·1**	**60,675**	0·88 1·08 0·60	**0·85**	**7·6**	**11·2**	22 2*i* 1		t v t t
238	**23·4**	**71,441**	1·26 1·00 0·85	**1·04**	**7·6**	**13·7**	60 0 73		v t **v**
154	**15·3**	**58,545**	0·86 0·70 0·46	**0·67**	**7·6**	**8·8**	3*i* 10 40*i*		t w t w **w**
135	**18·3**	**65,554**	0·71 0·63 0·85 0·86 0·97 0·97	**0·83**	**6·6**	**12·6**	18 7 13 15 1 0	Close and uniform.	t v t t v t v t t
244	**41·4**	**104,468**	1·37 1·36 1·45 1·33	**1·38**	**6·6**	**20·9**	0 0 0 0	Soft and very fine.	s s **s** s

SUMMARY OF RE

Linear

NOTE.—All the pieces were taken *promiscuously* from Engineers'

Reference No.	No. of Experiments in each.	Names of the Makers or Works.	Condition.	Index Nos	BREAKING WEIGH Per Square Inch of *Original.*			
					Lowest.		Highest.	
					a.	1. lbs.	b.	2. lbs.
1	6	TURTON'S Cast-steel for Tools.	Forged.	1-6	3	112,242	2	145,383
2	4	JOWITT'S Cast-steel for Tools.	"	7-10	1	117,719	1	148,294
3	8	Do. Cast-steel for Chisels.	"	11-18	2	112,334	3	137,979
4	4	Do. Double-shear-steel.	"	23-26	4	106,747	5	125,321
5	4	Do. Cast-steel for Drifts.	"	19-22	8	96,653	4	130,447
6	8	BESSEMER'S Patent steel for Tools. *S.*	"	27-34	5	103,255	6	123,165
7	4	MOSS & GAMBLE, Cast-steel for Rivets. *S.*	Rolled.	43-46	6	101,422	7	116,763
8	4	NAYLOR, VICKERS, & Co.'s do. Rivets.	"	47-50	7	101,421	9	112,262
9	4	WILKINSON'S Blister-steel.	Forged.	35-38	9	89,546	8	116,183
10	4	JOWITT'S Cast-steel for Taps.	"	39-42	12	84,036	10	110,697
11	4	KRUPP'S Cast-steel for Bolts.	Rolled.	51-54	10	86,054	12	96,208
12	4	SHORTRIDGE & Co.'s Homog. metal.	"	55-58	13	82,218	11	99,570
13	4	Do. do. Homog. metal.	Forged.	59-62	11	84,794	13	94,752
14	4	JOWITT'S Spring-steel.	"	63-66	14	65,158	14	82,719
15	6	MERSEY Co.'s Puddled-steel.	Forged.	69-74	1	67,065	1	75,304
16	6	BLOCHAIRN do.	Rolled.	75-80	2	55,006	2	75,114
17	6	Do. do.	Forged.	81-86	4	42,564	3	71,501
18	4	Do. do.	"	87-90	3	45,931	4	70,341
	88							

SUMMARY OF RES

Linearly r

NOTE.—All the pieces were taken *promiscuously* from Engineers'

Reference No.	No. of Experiments on each.	Names of the Makers or Works.	Thick.	Length-Cross	Index No.	BREAKING WEIGHT Per Square Inch of *Original*				
						Lowest.		Highest.		Mean.
						a.	1. lbs.	b.	2. lbs.	c.
51	4	TURTON & SON, Cast-steel. *S.*	$\frac{1}{4}$	L	301-304	1	92,858	2	95,360	2
52	4	" " "	"	C	305-308	1	92,788	2	99,952	2
53	5	SHORTRIDGE & Co., do.	$\frac{3}{16}$	L	331-335	2	85,650	1	108,900	1
54	5	" " "	"	C	336-340	2	84,211	1	105,732	1
55	6	NAYLOR, VICKERS, & Co., do. *S.*	$\frac{1}{4}$	L	309-314	3	76,772	3	87,972	3
56	6	" " " *S.*	"	C	315-320	3	82,428	3	95,196	3
57	7	MOSS & GAMBLES, do. *S.*	$\frac{3}{16}$ & $\frac{4}{16}$	L	321-327	4	67,977	4	81,588	4
58	3	" " " *S.*	"	C	328-330	4	67,538	4	71,796	4
59	1	SHORTRIDGE & Co., do.	$\frac{5}{8}$	C	341		—		—	
60	4	MERSEY COY. Puddled-steel.	$\frac{2}{16}$ $\frac{3}{16}$	L	348-351	4	92,676	1	108,906	3
61	4	" " "		C	352-355	5	63,098	2	99,468	2
62	3	MERSEY COY. "Hard," do. *S.*	" $\frac{1}{4}$ "	L	356-358	1	95,946	3	106,110	1
63	2	" " " " *S.*	"	C	359-360	1	82,200	1	88,529	1
64	5	BLOCHAIRN " do. *S.*	$\frac{5}{16}$	L	367-371	3	93,327	2	106,394	2
65	5	" " " *S.*	"	C	372-376	2	81,017	3	89,447	3
66	2	BLOCHAIRN do.	$\frac{5}{16}$	L	377-378	2	95,227	4	97,413	4
67	2	" " "	"	C	379-380	3	71,792	4	75,606	4
68	4	SHORTRIDGE & Co. do. *S.*	$\frac{1}{4}$	L	342-345	6	62,435	6	81,662	6
69	2	" " " *S.*	"	C	345-347	6	62,435	5	84,724	5
70	2	MERSEY COY. "Mild," do. *S.*	$\frac{1}{4}$	L	361-362	5	67,184	5	86,908	5
71	2	" " " " *S.*	"	C	363-364	4	66,524	6	68,848	6
72	2	MERSEY COY. do. do.	$\frac{9}{32}$	L	365-366		65,045		78,020	
	80									

F, STEEL BARS.

te VI.

hose marked *S.*, which were received from the Makers

WEIGHT inch of Area.		CONTRACTION OF AREA.				ELONGATION,		CHARACTERISTICS OF FRACTURE.	
Fractured.		*Stretched.*		*Fractured.*		*Extreme.*			
Mean.		Mean.		Mean.		Mean.			
f.	6.	h.	8.	i.	9.	l.	11.	Gran.	
	lbs.		℔ cent.		℔ cent.		℔ cent.	℔ ct.	
11	139,124	1	4·7	1	4·7	2	5·4	100	Wholly granular, very fine.
3	151,857	3	5·1	2	12·8	1	5·2	100	
4	150,243	5	8·0	3	17·0	4	7·1	100	
6	147,396	4	7·8	4	19·6	11	13·5	97	Granular, and fibrous of a very fine silky lustre.
5	147,570	13	14·3	6	21·5	10	13·3	78	
7	143,327	2	4·8	7	22·3	3	5·5	90	
2	158,013	7	9·1	11	32·1	9	12·4	54	
1	158,785	8	9·1	12	32·8	5	8·7	90	
12	132,472	6	8·4	5	21·4	6	9·7	97	
9	142,070	9	9·4	10	28·8	7	10·8	94	
10	139,434	12	13·1	13	34·0	13	15·3	49	
8	142,920	11	12·9	14	36·6	12	13·7	30	
13	121,212	10	12·2	9	26·0	8	11·9	92	
14	95,490	14	16·2	8	24·1	14	18·0	20	Granular, fibrous, & crystalline.
1	110,451	4	18·2	4	35·3	4	19·1	6	Granular & fibrous, uniform.
2	84,871	3	10·9	3	19·4	2	11·3	14	Granular & fibrous, irregular.
3	80,370	2	10·5	2	19·0	3	12·0	0	
4	71,231	1	6·4	1	11·9	1	9·1	12	

H, STEEL PLATES.

VI.

hose marked *S.*, which were received from the Makers.

VEIGHT tured Area.		CONTRACTION of Area at *Fracture.*				ELONGATION, *Extreme.*				CHARACTERISTICS OF FRACTURE.	
Mean.		Mean.		Mean.		Mean.		Mean.			
7.	g.	i.	9.	10.	k.	l.	11.	12.	m.	Gran.	
lbs.			℔ ct.				℔ ct.			℔ ct.	
05,937	4	1	5·6	9·5	1	1	5·71	7·68	1	100	Wholly granular, very fine.
		1	13·4			2	9·64			100	
14,203	1	2	15·6	15·2	2	2	8·61	8·77	2	60	Granular and fibrous, very fine.
		2	14·8			1	8·93			67	
08,125	3	3	21·4	21·7	3	3	17·50	17·41	3	40	
		3	22·0			3	17·32			24	
09,050	2	4	28·2	33·4	4	4	19·82	19·73	4	0	Wholly fibrous, very soft and fine.
		4	38·6			4	19·64			0	
			14·4				14·4			100	Wholly granular, very fine.
00,649	1	3	6·4	5·4	3	1	2·79	2·02	1	16	Laminated fibrous, slightly granular.
		3	4·4			1	1·25			10	
98,472	2	1	4·5	4·6	1	3	4·86	4·08	3	76	Laminated granular and fibrous.
		4	4·7			4	3·30			58	
97,978	3	2	5·3	4·8	2	2	3·60	3·14	2	78	
		2	4·2			2	2·68			49	
92,130	4	4	10·4	7·1	4	6	8·22	6·18	6	23	Laminated fibrous, and slightly granular.
		1	3·8			5	4·14			18	
80,034	6	5	11·5	8·6	5	5	5·93	4·57	4	0	
		5	5·7			3	3·21			5	
80,937	5	6	12·5	10·5	6	4	6·16	5·94	5	16	
		6	8·5			6	5·72			1	
			7·5				3·57			0	Laminated, wholly fibrous.

SUMMARY OF RESU

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Note.—All the pieces were taken *promiscuously* from Engineers' or

Reference No.	No. of Experiments in each.	Names of the Makers or Works.	Shape.	Size.	Index Nos.	BREAKING WEIGHT Per Square Inch of Area, *Original.*				
						Lowest.		Highest.		
						a.	1. lbs.	b.	2. lbs.	c.
		ROLLED BARS.								
101	4	Bradley & Co. Ⓛ *S.*	Round.	1	133-136	21	56,004	31	58,036	27
102	4	Lowmoor.	"	1	105-108	8	59,320	5	65,166	8
103	4	Farnley.	"	1	129-132	6	59,642	7	64,133	3
104	4	Bradley & Co. B. B. Scrap. *S.*	"	1	137-140	13	58,571	18	59,998	14
105	4	Lowmoor.	Square.	1	101-104	9	59,202	10	62,298	11
106	4	Bowling.	Round.	1	121-124	11	58,678	4	65,701	5
107	4	◈ Govan. ◈	"	⅝	725-728	24	55,526	17	60,558	22
108	4	" "	"	1	721-724	15	57,738	21	59,726	19
109	4	" "	"	1¼	709-712	20	56,067	24	59,302	24
110	4	Govan Ex. B. Best.	"	⅞	173-176	18	56,595	26	59,104	23
111	4	Glasgow B. Best.	"	⅝	741-744	12	58,671	19	59,929	15
112	4	Govan Ex. B. Best.	Square.	¾	157-160	25	55,297	33	57,328	28
113	4	" "	Round.	1	169-172	14	58,252	22	59,726	16
114	4	" "	"	1⅛	165-168	17	57,362	25	59,276	20
115	4	Bradley & Co. ♔ S C	"	⅞	145-148	3	61,263	8	63,604	6
116	4	Glasgow B. Best.	"	$\frac{15}{16}$	218-221	22	55,913	13	61,296	17
117	5	" "	"	1	213-217	19	56,121	15	60,817	
118	4	Govan B. Best.	"	¾	193-196	2	61,864	2	66,553	
119	4	" "	"	¾	231-234	10	58,886	14	61,106	
120	4	" "	"	⅞	189-192	4	60,453	11	62,229	
121	4	✱ Govan. ✱	"	¾	209-212	7	59,493	9	63,547	
122	4	Govan Ex. B. Best.	"	¾	161-164	23	55,653	27	59,070	
123	4	" "	"	¾	177-180	30	53,266	20	59,820	
124	4	Blochairn B. Best.	"	1	761-764	28	53,972	30	58,049	
125	5	Malinslee ♔ Best.	Flat.	⅜ × 1	296-300	29	53,866	28	58,661	
126	6	Port-Dundas Ex. B. Best.	Round.	1⅛	765-770	35	44,584	32	57,692	
127	4	Glasgow B. Best.	"	1¼	729-732	31	52,776	34	56,404	
128	4	Govan B. Best.	"	1⅛	181-184	26	54,245	6	64,575	
129	4	" "	"	1	185-188	5	60,069	3	66,363	
130	4	✱ Govan ✱	"	⅞	205-208	1	62,845	1	66,630	
131	4	" "	"	1	201-204	16	57,738	16	60,722	
132	4	" "	"	1⅛	197-200	32	52,348	12	61,594	
133	4	Bagnall ♔ J B	"	1¼	701-704	27	54,123	35	56,067	
134	4	Dundyvan.	"	1	757-760	33	48,966	23	59,657	
135	4	"	"	1¼	745-748	34	45,611	29	58,640	
136	4	Ystalyfera Puddled.	Flat.	⅝ × 1	779-782	36	36,979	36	40,977	
	148	**ROLLED BARS FOR RIVETS.**								
137	4	Lowmoor.	Round.	$\frac{11}{16}$	109-112	3	58,228	4	62,451	
138	4	Bradley & Co. ♔ S C.	"	¾	141-144	8	54,575	10	58,632	
139	8	Ulverston Rivet Best.	"	¾	251-258	10	47,095	7	59,330	
140	4	Thorneycroft & Co. T N S.	"	$\frac{13}{16}$	149-152	4	57,431	5	60,528	
141	4	R. Solloch E. Best.	"	$\frac{11}{16}$	247-250	7	55,078	8	59,226	
142	4	Coatbridge Best Rivet.	"	¾	235-238	1	59,013	2	63,577	
143	4	Glasgow Best Rivet.	"	⅞	222-225	6	56,515	9	58,823	
144	4	Lord Ward L ♔ W. R. O.	"	$\frac{11}{16}$	153-156	5	57,188	3	63,373	
145	4	Blochairn Best Rivet.	"	¾	239-242	2	58,506	6	59,900	
146	4	St. Rollox Best Rivet.	"	$\frac{13}{16}$	243-246	9	47,248	1	68,848	
	44									

BLE G. IRON BARS.

am-Plates VII. VIII.

, except those marked *S.*, which were received from the Makers.

BREAKING WEIGHT Per Square Inch of Area.			CONTRACTION OF AREA.				ELONGATION,		CHARACTERISTICS OF FRACTURE.	
tretched.	*Fractured.*		*Stretched.*		*Fractured.*		*Extreme.*			
Mean.	Mean.		Mean.		Mean.		Mean.			
5.	f.	6.	h.	8.	i.	9.	l.	11.	Crys.	
lbs.		lbs.		℔ cent.		℔ cent.		℔ cent.	℔ ct.	
72,700	1	146,521	1	21·2	1	60·9	1	30·2	0	Bright grey, very fine and soft.
76,290	2	131,676	3	19·0	2	53·1	2	26·5	0	Bright lightish grey, close, and very fine.
77,200	3	127,425	4	18·5	4	50·6	4	25·6	0	
74,378	4	123,805	2	19·9	3	52·0	3	26·6	0	
70,131	5	117,147	16	13·9	7	48·5	6	24·9	1	
74,487	8	114,220	8	16·2	9	45·3	8	24·4	0	
64,675	6	116,549	33	10·0	5	50·1	13	21·4	0	Light grey, uniformly fine.
67,708	9	113,700	19	13·2	8	48·3	5	25·2	0	
64,630	7	114,866	31	10·9	6	49·8	7	24·8	0	
68,446	10	101,863	13	15·0	10	42·9	21	19·2	0	Brightish grey, close, and uniform.
68,160	11	99,612	20	13·0	12	40·4	19	20·0	0	
64,797	12	99,000	24	12·6	11	42·7	22	19·1	0	
68,140	13	98,527	18	13·3	15	40·0	11	22·3	0	
70,645	14	97,821	5	17·4	13	40·3	9	23·8	0	
75,133	15	97,575	6	17·2	23	36·2	12	22·2	15	Bright grey, fine, but irregular.
67,404	16	97,559	25	12·6	14	40·3	14	21·3	0	Brightest grey, close, and generally uniform.
70,260	17	97,548	9	16·2	16	39·6	10	23·2	2	
74,246	18	97,245	27	12·5	27	33·4	27	17·3	6	
67,333	20	95,706	29	11·5	20	37·7	30	16·9	0	
73,527	19	96,442	7	16·6	22	36·4	20	20·0	13	
73,869	21	95,319	10	16·1	26	35·1	24	18·8	3	
66,242	22	95,248	21	13·0	17	39·5	26	17·3	0	
68,018	23	92,880	11	15·6	18	38·0	25	17·6	0	
66,272	24	90,313	12	15·3	19	37·8	16	21·3	3	
65,596	27	88,300	14	14·2	21	37·0	15	21·4	19	Generally close and fine, but irregular.
62,645	28	85,563	23	12·7	24	36·1	17	20·6	13	
61,496	29	85,012	30	11·2	25	35·8	18	20·3	5	
69,161	30	84,770	28	12·0	29	28·2	29	17·0	43	
73,111	25	88,550	17	13·7	28	28·9	23	19·1	26	
74,535	26	88,512	15	14·2	30	27·7	33	15·8	35	Rather coarse and irregular.
68,106	31	79,373	26	12·6	33	25·1	32	16·4	34	
67,046	32	78,139	22	13·0	32	25·3	31	16·7	25	
61,700	33	75,351	32	10·9	31	27·0	28	17·3	15	
56,889	34	58,304	34	6·2	34	8·5	34	6·8	91	Coarse and very hard.
53,436	35	54,100	35	4·0	35	5·1	35	6·3	98	
38,996	36	39,470	36	1·2	36	2·4	36	2·0	74	Coarse and open.
72,685	1	125,775	3	17·3	1	52·2	6	20·5	0	Uniformly very fine and soft.
70,503	2	112,336	2	19·5	2	49·5	2	22·5	0	
67,324	3	104,680	1	20·1	3	48·6	4	21·6	0	
71,540	4	99,595	4	17·1	6	40·4	3	22·4	0	Generally fine and uniform.
65,590	5	96,959	8	12·4	5	40·7	9	17·7	0	
70,893	6	96,267	7	13·2	8	35·9	5	21·6	0	
67,103	7	96,205	6	14·9	4	40·7	1	23·7	1	
71,621	8	95,724	5	16·4	7	37·6	8	18·6	1	
67,505	9	89,279	9	12·2	9	34·3	7	19·4	0	
63,325	10	77,383	10	9·6	10	26·3	10	16·6	42	Extremely irregular and hard.

Linearly r

Note.—All the pieces were taken *promiscuously* from Engineers' or

Reference No.	No. of Experiments in each.	Names of the Makers or Works.	Shape.	Size	Index Nos	Breaking Weight Per Square Inch of Area. *Original.* Lowest. a.	Lowest. 1. lbs.	Highest. b.	Highest. 2. lbs.	c.
		ROLLED BARS, TURNED.								
147	4	Bowling.	Round.	1	125-128	1	59,570	1	62,885	1
148	4	◈ Govan ◈	,,	1	713-716	3	56,005	4	59,605	3
149	4	Lowmoor, (planed.)	Square.	¾	113-116	2	59,135	2	61,805	2
150	4	Glasgow B. Best.	Round.	1	733-736	4	53,844	5	57,738	5
151	4	Bagnall 𝔚 J B	,,	1	705-708	5	53,723	6	56,539	6
152	4	Dundyvan.	,,	1	749-752	6	51,905	3	60,069	4
	24									
		ROLLED BARS, FORGED.								
153	4	Lowmoor.	Round.	¾	117-120	1	64,871	1	67,876	1
154	4	◈ Govan ◈	,,	1	717-720	4	56,000	8	58,740	4
155	5	Mersey Co. Best.	,,	¾	259-263	2	57,690	3	62,411	2
156	4	Glasgow B. Best.	,,	1	737-740	5	51,846	5	59,506	5
157	5	Do. do.	,,	⅞	226-230	3	56,316	4	60,695	3
158	4	Dundyvan.	,,	1	753-756	6	48,014	2	62,429	6
159	4	Govan Puddled.	,,	1	771-774	7	33,150	7	55,323	7
160	4	Ystalyfera Puddled.	,,	1¼	775-778	8	20,521	8	39,000	8
	34									
		HAMMERED,								
161	4	Scrap-iron, forged down.			280-283	2	52,665	2	54,070	2
162	4	Busheled-iron, forged down.			284-287	1	54,070	1	57,526	1
163	6	Crank Shaft, Scrap-iron, cut out, Length			288-293	3	46,450	3	49,671	3
164	6	Do. do. do. Length			783-788	5	43,420	5	41,561	5
165	2	Do. do. do. Cross			294-295	4	44,453	4	44,703	4
166	8	Do. do. do. Cross			789-796	8	32,582	7	40,467	7
167	3	Armour Plate, do. Cross			797-799	6	36,646	6	40,745	6
168	3	Do. do. do. Cross			800-802	7	34,614	8	39,213	8
	36									
		FOREIGN TILTED BARS.								
169	4	Swedish R F			264-267		47,384		48,987	
170	4	Russian C C ND			272-275		44,600		55,190	
171	1	Swedish OC			803		——		——	
172	1	Swedish 𝔚 𝔷 W			804		——		——	
173	1	Swedish 𝔚 C			805		——		——	
174	1	Russian IO P 3			806		——		——	
	12									
		FOREIGN TILTED BARS, FORGED.								
175	4	Swedish R F			268-271		46,869		49,505	
176	4	Russian C C ND			276-279		52,334		65,516	
177	1	Swedish OC			807		——		——	
178	1	Swedish 𝔚 C			808		——		——	
179	1	Swedish 𝔇 𝔈 W			809		——		——	
180	1	Russian IO P 3			810		——		——	
	12									
	310									

.E G, IRON BARS.

lates VII. VIII.

ept those marked *S.*, which were received from the Makers.

.KING WEIGHT uare Inch of Area.			CONTRACTION OF AREA.				ELONGATION.			CHARACTERISTICS OF FRACTURE.
d.	*Fractured.*		*Stretched.*		*Fractured*		*Extreme.*			
	Mean.		Mean.		Mean.		Mean.			
.	f.	6.	h.	8.	1.	9.	1.	11.	Crys.	
s.		lbs.		₰ cent.		₰ cent.		₰ cent.	₰ ct.	
63	1	120,229	1	16·7	2	48·8	1	26·0	0	Light grey, very fine and uniform.
55	2	116,869	3	12·5	1	51·0	2	25·6	0	
40	3	114,410	4	12·5	3	47·3	3	23·8	0	
34	4	86,590	2	15·0	4	35·8	4	21·3	8	Close and fine, but irregular.
24	5	80,638	5	11·1	5	31·3	5	19·1	9	Rather coarse and irregular.
24	6	63,280	6	6·4	6	11·5	6	11·1	70	Coarse and very hard.
83	1	115,040	1	14·2	2	42·3	3	20·2	0	Very fine and uniform.
70	2	112,705	3	12·1	1	49·2	1	23·1	0	
94	3	86,295	5	8·2	4	30·5	5	16·9	15	Fine, but rather irregular.
77	4	81,508	4	10·4	3	31·1	4	18·6	7	
03	5	80,053	2	13·1	5	26·2	2	20·9	25	
72	6	60,856	6	7·5	6	10·8	6	7·3	75	Coarse and very hard.
92	7	48,057	7	1·6	7	3·2	7	3·4	78	Coarse and very irregular.
26	8	29,818	8	0·0	8	0·0	8	0·6	82	
18	1	94,105	1	20·5	1	43·2	1	24·8	0	Bright grey, close, and fine.
70	2	72,531	2	14·7	3	22·9	5	16·6	5	
10	3	59,003	3	12·8	4	20·7	2	23·1	72	Whitish grey and lustrous.
23	4	56,910	4	11·3	2	23·1	3	20·5	44	
17	5	50,971	5	10·7	6	12·5	4	16·8	60	
91	7	42,029	7	6·1	7	8·5	7	8·4	36	
67	6	44,611	6	9·1	5	12·8	6	11·7	6	Laminated, fibrous.
98	8	39,085	8	3·9	8	5·9	8	6·4	2	
84		121,065		16·8		60·5		27·8	0	Very soft, and uniformly fine.
59		73,118		10·7		32·1		13·3	18	Very fine, but extremely varied.
45		141,702		13·1		65·5		17·0	0	
64		77,349		16·3		43·7		15·3	0	
56		63,632		11·9		33·3		15·2	0	
60		68,047		3·4		13·1		6·0	55	
85		150,760		12·7		68·0		26·4	0	Very soft and uniformly fine.
95		77,632		12·4		28·1		15·3	47	Very fine, but extremely varied.
01		188,731		9·4		73·3		18·7	0	
74		98,510		11·4		58·1		14·8	0	
34		83,851		15·7		47·2		15·8	0	
70		67,907		9·2		24·2		7·5	2	

SUMMARY OF RESU

Linearly rep

NOTE.—All the pieces were taken *promiscuously* from Engineers' or

Reference No.	No. of Experiments on each.	Names of the Makers or Works.	Thick.	Length, Cross	Index No.	BREAKING WEIGHT Per Square Inch of *Original Ar* Lowest.		Highest.		Mean.	
						a.	1. lbs.	b.	2. lbs.	c.	3. lbs.
201	4	FARNLEY. *S.*	¾	L	438-441	1	56,172	1	62,544	2	58,437
202	4	,, *S.*	,,	C	442-445	1	52,955	2	56,546	1	55,033
203	3	FARNLEY.	¼	L	429-431	2	55,631	2	61,184	1	58,487
204	6	,,	,,	C	432-437	2	49,612	1	60,756	2	54,098
205	5	LOWMOOR.	5/16	L	401-405	15	47,426	7	57,881	15	52,000
206	5	,,	,,	C	406-410	5	47,426	5	55,368	6	50,515
207	4	FARNLEY.	⅜	L	421-424	7	51,541	5	59,443	4	56,005
208	4	,,	,,	C	425-428	18	40,541	13	50,136	15	46,221
209	5	BOWLING.	⅜	L	411-415	8	51,443	17	53,488	14	52,235
210	5	,,	,,	C	416-420	14	43,074	14	50,136	14	46,441
211	6	◇ GOVAN. ◇	13/32	L	968-973	10	50,953	10	57,659	8	54,644
212	6	,, ,, ,,	,,	C	974-979	8	46,127	9	52,303	8	49,399
213	3	BRADLEY & CO. ♔ S C	½	L	453-455	4	53,889	6	58,534	5	55,831
214	3	,, ,, ,,	,,	C	456-458	3	47,532	4	55,414	5	50,550
215	6	BRADLEY & CO. L F	⅜ to ½	L	459-464	3	54,687	3	60,985	3	56,995
216	6	,, ,,	,,	C	465-470	6	47,410	3	55,697	3	51,251
217	3	BRADLEY & CO.	⅜ to ½	L	471-473	9	51,295	4	60,697	6	55,708
218	3	,, ,,	,,	C	474-476	7	47,238	11	51,025	7	49,425
219	2	MALINSLEE ♔ Best.	⅜	L	859-860	6	52,466	19	52,679	12	52,572
220	2	,, ,,	,,	C	861-862	4	47,453	6	53,801	4	50,627
221	3	CONSETT Best Best.	¾	L	446-448	14	47,613	16	54,403	16	51,245
222	4	,, ,,	,,	C	449-452	9	46,062	19	47,613	12	46,712
223	10	Do. Do.	7/16 & 9/16	L	911-920	11	49,850	9	57,760	10	53,559
224	10	,, ,,	,,	C	921-930	17	40,807	12	50,362	16	45,677
225	24	Do. Do.	7/16 to 14/16	L	863-886	21	41,130	14	55,758	17	49,120
226	24	,, ,,	,,	C	887-910	16	40,873	7	53,353	11	46,755
227	3	THORNEYCROFT Best Best.	15/16	L	941-943	5	52,507	13	56,080	7	54,847
228	2	,, ,,	,,	C	944-945	11	44,425	21	46,745	17	45,585
229	5	SNEDSHILL ♔ Best.	5/16 to 7/16	L	931-935	13	47,684	12	56,233	13	52,362
230	5	,, ,,	,,	C	936-940	19	38,905	20	47,255	21	43,036
231	6	WELLS Best ♔ Best. *S.*	10/16 & 12/16	L	946-951	23	40,192	20	52,021	22	45,997
232	6	,, ,, *S.*	,,	C	952-957	13	44,184	10	52,035	9	49,311
233	6	GLASGOW Best Boiler.	⅜ to 11/16	L	503-508	12	48,016	11	56,317	9	53,849
234	6	,, ,,	,,	C	509-514	10	45,761	8	52,959	10	48,848
235	18	GLASGOW Best Best.	¼ to ¾	L	573-590	16	46,528	8	57,804	11	53,399
236	14	,, ,,	,,	C	591-854	23	37,237	17	49,083	22	41,791
237	7	WELLS Best ♔ Best.	5/16 & 8/16	L	477-483	22	41,002	15	54,406	20	47,410
238	7	,, ,,	,,	C	484-490	15	42,581	15	49,441	13	46,630
239	6	Maker's Stamp uncertain.	4/16 to 11/16	L	527-532	17	43,290	22	49,838	19	47,598
240	6	,, ,,	,,	C	533-538	22	37,330	24	44,512	25	40,682
241	3	K. B. M.	5/16	L	491-493	18	43,232	21	51,285	21	46,401
242	3	,,	,,	C	494-496	12	44,195	22	45,402	18	44,764
243	5	LLOYDS, FOSTER, & CO., Best.	6/16 to 7/16	L	958-962	20	42,690	25	47,609	24	44,967
244	5	,, ,,	,,	C	963-967	25	35,007	18	47,903	19	44,732
245	11	GLASGOW Best Best.	7/16 to 11/16	L	551-561	24	38,605	24	48,544	23	45,626
246	11	,, ,,	,,	C	562-572	21	37,878	23	45,379	24	41,340
247	6	GLASGOW Ship.	5/16 to 11/16	L	515-520	26	37,474	18	53,370	18	47,773
248	6	,, ,,	,,	C	521-526	26	32,450	16	49,812	20	44,355
249	3	MOSSEND Best Best.	⅜	L	497-499	19	43,012	26	43,992	26	43,433
250	3	,, ,,	,,	C	500-502	20	38,007	25	43,875	23	41,456
251	6	GOVAN Best.	¼ to ½	L	539-544	25	38,398	23	49,677	25	43,912
252	6	,, ,,	,,	C	545-550	24	36,460	26	43,069	26	39,544
253	4	GLASGOW Best Scrap.	⅜	L	855-858		47,069		53,553		50,844
	329										

E J, IRON PLATES.

ate IX.

t those marked *S*, which were received from the Makers.

WEIGHT ractured Area.		CONTRACTION of *Area at Fracture.*				ELONGATION, *Extreme.*				CHARACTERISTICS OF FRACTURE.	
Mean.			Mean.	Mean.			Mean.	Mean.			
7. lbs.	g.	i.	9. ℔ cent.	10.	k.	l.	11. ℔ cent.	12.	m.	Crys. ℔ ct.	
76,036	1	1	29·6	24·8	1	1	17·0	14·15	1	4	Light grey, of various shades, close, and very fine.
		1	20·1			1	11·3			27	
65,118	2	2	20·0	15·7	3	10	10·9	8·40	8	0	
		4	11·4			7	5·9			0	
61,065	5	3	19·7	15·9	2	3	13·2	11·25	2	0	
		3	12·1			2	9·3			0	
61,028	6	5	17·8	15·5	4	2	14·1	10·85	3	1	
		2	13·2			3	7·6			0	
55,862	11	8	15·3	11·1	11	7	11·6	8·75	7	19	
		12	6·9			8	5·9			8	
60,374	7	4	18·1	13·3	5	6	11·6	9·05	5	0	
		10	8·5			5	6·5			0	
61,306	4	6	17·2	13·1	6	5	12·5	9·00	6	3	Dullish grey, of various shades, close, and generally fine.
		8	9·0			11	5·5			3	
61,464	3	9	15·0	11·8	8	4	13·0	9·45	4	12	
		9	8·6			9	5·9			9	
59,827	8	11	14·9	11·5	10	11	10·7	7·90	9	17	
		11	8·1			13	5·1			15	
58,939	9	7	15·4	12·4	7	16	8·6	7·20	13	17	
		7	9·3			10	5·8			22	
55,616	12	13	13·1	11·7	9	15	8·9	7·68	12	42	
		6	10·2			6	6·4			27	
55,352	13	12	14·4	10·0	14	8	11·5	7·75	11	15	
		17	5·6			18	4·0			6	
52,736	17	15	11·3	8·8	15	17	8·0	6·60	16	17	
		15	6·3			12	5·2			15	
55,230	14	14	12·5	8·6	17	9	11·2	7·90	10	51	
		22	4·6			15	4·6			35	
53,541	15	10	15·0	10·2	13	12	9·6	6·20	17	10	
		18	5·3			21	2·8			25	
52,991	16	18	10·4	10·5	12	18	6·7	6·85	15	5	Dull grey, generally rather coarse and irregular.
		5	10·5			4	7·0			2	
56,387	10	16	11·0	8·8	16	13	9·3	6·95	14	43	
		14	6·6			14	4·6			36	
51,585	18	17	10·6	7·2	21	14	9·0	5·79	18	52	
		23	3·7			22	2·6			25	
49,935	19	22	6·7	5·8	22	23	4·0	3·70	22	10	
		20	4·9			19	3·4			10	
48,304	22	20	9·8	7·4	20	20	5·9	4·20	21	16	
		19	5·0			23	2·5			10	
49,893	20	19	10·2	8·3	18	19	6·1	5·20	19	1	
		16	6·4			17	4·3			5	
48,753	21	21	8·7	7·8	19	21	5·3	4·95	20	17	
		13	6·9			16	4·6			22	
45,319	24	25	5·3	3·8	26	22	4·3	3·35	23	41	Irregular, generally coarse and open.
		26	2·2			24	2·4			31	
47,580	23	26	4·8	4·1	25	24	3·6	2·83	25	48	
		24	3·4			25	2·1			49	
44,830	25	24	5·7	5·3	23	26	3·3	3·10	24	22	
		21	4·9			20	2·9			16	
43,255	26	23	6·0	4·3	24	25	3·4	2·40	26	12	
		25	2·6			26	1·4			10	
			13·0				10·5			23	Close and fine.

SUMMARY OF RESU

Linearly repre

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Ma

Reference No.	No. of Experiments in each	Names of the Makers or Works	Size.	Index Nos.	BREAKING WEIGHT Per Square Inch of Area. *Original.*				
					Lowest.		Highest.		
					a.	1.	b.	2.	c.
						lbs.		lbs.	
		ANGLE-IRON.							
271	4	FARNLEY.	$\frac{9}{16}$	669-672	1	58,772	1	63,715	1
272	6	GLASGOW Best Scrap.	$\frac{5}{8}$	626-631	4	53,594	3	58,353	3
273	3	EAGLE Best Best.	$\frac{5}{8}$	657-659	5	53,396	7	56,534	6
274	4	GLASGOW Best Best.	$\frac{9}{16}$	632-635	2	54,967	5	57,119	4
275	3	ALBION ⵉ Best.	$\frac{5}{8}$	648-650	3	54,061	4	57,917	2
276	3	ALBION Best.	$\frac{5}{8}$	651-653	7	51,789	12	52,333	9
277	4	GLASGOW Best Best.	$\frac{9}{16}$	640-643	11	47,012	6	57,123	8
278	6	CONSETT Best Best.	$\frac{1}{4}$	663-668	6	52,334	8	56,109	7
279	4	GLASGOW Best Best.	$\frac{5}{8}$	644-647	9	50,892	11	52,491	10
280	3	ALBION Best.	$\frac{11}{16}$	654-656	10	50,044	10	52,807	11
281	4	GLASGOW Best Best.	$\frac{3}{8}$	636-639	8	51,284	2	59,336	5
282	3	EAGLE.	$\frac{21}{32}$	660-662	12	46,457	13	52,333	13
283	4	CONSETT.	$\frac{9}{16}$	618-621	13	43,037	9	54,962	12
	51								
		SHIP STRAP, AND BEAM-IRON.							
284	4	GLASGOW.	$\frac{3}{8}$ $\frac{1}{2}$	601-604	2	54,006	1	60,455	1
285	4	DUNDYVAN.	$\frac{1}{2}$ $\frac{11}{16}$	605-608	1	54,444	3	56,538	2
286	6	THORNEYCROFT.	$\frac{1}{2}$	612-617	3	48,141	2	56,649	3
287	3	MOSSEND.	$\frac{9}{16}$ 1	609-611	4	39,534	4	51,985	4
288	4	DOWLAIS.	$\frac{1}{2}$	622-625	5	37,909	5	43,817	5
	21								

BLE K, ANGLE-IRON, &c.

m-Plate X.

except those marked *S.*, which were received from the Makers.

ING WEIGHT are In of Area, *Fractured.*	CONTRACTION OF AREA, *Fractured.*		ELONGATION, *Extreme.*		CHARACTERISTICS OF FRACTURE.	
Mean.	Mean.		Mean.			
7.	1.	9.	1.	11.	Crys.	
lbs.		℘ cent.		℘ cent.	℘ cent.	
104,468	1	41·4	1	20·9	0	Soft and very fine.
71,764	6	20·1	3	15·0	44	Close, fine, and uniform.
71,441	2	23·4	6	13·7	44	
70,706	4	20·9	2	15·4	43	
69,367	7	19·1	5	14·0	33	Generally fine, but rather varied.
67,693	3	22·8	4	14·1	10	
65,770	8	18·9	7	12·8	19	
65,554	9	18·3	9	12·6	9	
64,962	5	20·3	8	12·7	35	
60,675	11	15·1	10	11·2	8	
62,373	13	11·0	12	8·5	53	
58,545	10	15·3	11	8·8	18	
58,201	12	11·7	13	5·8	14	Fine, but rather open.
67,606	1	16·9	1	10·8	15	Generally fine, but varied.
63,635	2	13·0	2	8·0	26	
59,918	3	12·1	3	8·0	15	
50,459	5	9·2	4	5·2	48	Rather coarse and irregular.
45,844	4	9·8	5	4·8	12	Loose and irregular.

RATE OF ELONGAT

These mark

The Measurements

NOTE.—All the pieces were taken *promiscuously* from Engineers' or

Reference No.	Names of the Makers or Works.	Description.	Index No. and Table.	Area of Specimen.	Ultimate Strength per sq. inch.	Ultimate Extension.			EXTENSION					
									14,548	16,116	17,684	19,252	20,830	22,4
	ROLLED IRON BARS.			sq. in.	lbs.	Original.	Increase.	Per cent.	3.	4.	5.	6.	7.	8.
301	† ◇ GOVAN. ◇	Rolled.	711 Table B.	1·2271	56,701	28·0	6·92	24·7		..		..		..
302	† GLASGOW B. Best.	,,	730	1·2271	55,697	30·0	7·28	24·3		..		..		..
303	† DUNDYVAN.	,,	745	1·2271	58,640	30·0	3·52	11·7		..		..		..
304	† BAGNALL ♛ J B	,,	703	1·2271	54,731	30·0	3·36	11·2		..		..		..
305	† LOWMOOR, (square.)	,,	103	1·0403	59,390	30·4	7·20	23·7		..		..		..
306	GOVAN B. Best.	,,	183	1·0029	62,201	28·0	5·68	20·3		..		..		..
307	† GOVAN Ex. B. Best.	,,	168	1·0387	57,362	28·0	6·24	22·3		..		..		..
308	PORT-DUNDAS Ex. B. Best.	,,	765	0·9852	57,692	28·0	6·96	24·9		..		..		..
309	† ✻ GOVAN. ✻	,,	200	1·0387	52,348	28·0	2·56	9·1		..		..		..
310	GOVAN B. Best.	,,	184	1·0029	54,245	28·0	1·44	5·1		..		..		..
311	† ✻ GOVAN. ✻	Rolled.	201	·8498	60,722	26·0	2·96	11·4		..		..		..
312	DUNDYVAN.	Forged.	753	·8333	62,429	30·0	5·04	16·7		..		..		..
313	† BOWLING.	Rolled.	122	·7854	63,634	28·8	7·20	25·0		..		..		..
314	† BOWLING.	Turned.	127	·7854	60,817	26·8	7·60	28·4		..		..		..
315	† FARNLEY.	Rolled.	129	·7854	64,133	27·2	7·20	26·5		..		..		..
316	† ◇ GOVAN. ◇	,,	721	·8171	59,726	24·0	6·52	27·2		..		..		..
317	GOVAN Ex. B. Best.	,,	169	·8171	59,726	26·0	6·80	26·2		..		..		..
318	DUNDYVAN.	,,	757	·8171	59,657	27·2	4·68	17·2		..		..		..
319	GLASGOW B. Best.	,,	738	·8333	57,590	26·0	4·92	19·0		..		..		..
320	† LOWMOOR.	,,	106	·7854	62,635	28·8	7·44	25·9		..		..		..
321	† BRADLEY B. B. Scrap. *S.*	Rolled.	138	·7854	59,570	30·4	8·24	27·1		..		..		..
322	† GOVAN B. Best.	,,	187	·7854	60,069	26·0	6·40	24·6		..		..		..
323	† DUNDYVAN.	Turned.	749	·7854	60,069	30·0	5·44	18·1		..		..		..
324	† GLASGOW B. Best.	,,	734	·8171	55,761	30·0	6·40	21·3		..		..		..
325	† BRADLEY B. B. Scrap. *S.*	Rolled.	140	·7854	58,571	30·4	7·60	25·0		..		..		..
326	† BRADLEY. Ⓛ *S.*	,,	136	·7854	56,004	25·6	7·44	29·1		..		..		..
327	BRADLEY. Ⓛ *S.*	,,	135	·7854	57,039	25·6	7·44	29·1		..		..		..
328	† ◇ GOVAN. ◇	Forged.	718	·7698	57,141	26·0	6·32	24·3		..		..		·10
329	† ◇ GOVAN. ◇	Turned.	714	·7854	57,003	30·0	7·80	26·0		..		..		·18
330	† BAGNALL ♛ J. B.	,,	706	·7854	56,005	30·0	5·52	18·4		..		..		·07
331	BLOCHAIRN B. Best.	Rolled.	764	·7854	53,972	27·2	6·40	23.5		..		..		·28
332	GLASGOW B. Best.	,,	217	·7698	56,121	32·0	7·48	23·4		..		..		·25
333	† MALINSLEE ♛ Best.	,,	297	·7500	57,520	26·8	6·24	23.3		..		..		·03
334	GLASGOW B. Best.	,,	218	·6650	61,296	24·0	5·60	23·3		..		..		·10
335	† BRADLEY ♛ S C	,,	146	·6220	62,344	29·2	7·40	25·3		..		·16		·30
336	✻ GOVAN. ✻	,,	207	·6362	62,845	26·0	4·28	17·8		..		·07		·14
337	† LOWMOOR, (square.)	Planed.	113	·6084	61,805	28·4	6·40	22·5		..		·30		·03
338	GOVAN B. Best.	Rolled.	191	·6220	60,453	24·0	5·64	23·5		..		·06		·16
339	GOVAN B. Best.	,,	192	·6220	60,453	24·0	4·00	16·7		..		·08		·15
340	GOVAN Ex. B. Best.	,,	173	·6362	59,104	24·0	4·64	19·3		..		·13		·29
341	GOVAN Ex. B. Best, (square.)	Rolled.	157	·5929	57,338	32·4	6·08	18·8		..		·29		·7
342	GLASGOW Best Rivet.	,,	223	·5945	56,515	21·6	5·12	23·7		..		·12		·25
343	† LOWMOOR.	Forged.	119	·5026	65,622	22·0	4·92	22·4		·05		·20		·3
344	GOVAN B. Best.	Rolled.	193	·4657	66,553	22·0	4·00	18·2		·08		·27		·3
345	† THORNEYCROFT, T N S	,,	152	·5153	57,431	29·6	6·16	20·8		·15		·60		1·1
346	ST. ROLLOX Best Rivet.	,,	245	·5185	55,726	27·2	4·12	15·1		·10		·50		1·0
347	✻ GOVAN. ✻	,,	211	·4657	61,804	23·2	4·88	21·0		·16		·40		0·9
348	GOVAN Ex. B. Best.	,,	177	·4657	59,820	22·0	4·48	20·4		·17	·30	·48	0·76	1·0
349	GOVAN Ex. B. Best.	,,	161	·4536	59,070	32·8	7·28	22·2		·37	·70	1·15	1·78	2·7
350	GOVAN B. Best.	,,	232	·4536	59,316	33·2	5·60	16·9		·22	·52	0·82	1·30	2·0
351	BLOCHAIRN Best Rivet.	Rolled.	241	·4417	59,013	27·2	5·00	18·4		·30	·60	0·95	1·45	2·0
352	† COATBRIDGE Best Rivet.	,,	238	·4417	59,013	27·2	4·68	17·2		·20	·50	0·92	1·38	2·0
353	† BRADLEY ♛ S C Rivet.	,,	143	·4417	55,463	27·2	5·68	20·9		·60	·82	1·15	1·85	2·7
354	† ULVERSTON Rivet, Best.	,,	253	·4417	58,000	26·8	5·52	20·6		·12	·45	0·80	1·22	1·8
355	LOWMOOR.	,,	109	·3712	62,451	26·4	5·24	19·9	·30	0·65	0·90	1·35	2·10	3·1
356	R. SOLLOCH E. Best.	,,	247	·3848	59,226	26·4	6·04	22·9	·20	0·55	1·00	1·65	2·77	4·3
357	LORD WARD L ♛ W R O	,,	156	·3848	57,188	25·6	3·68	14·4	·03	0·25	0·68	1·20	2·10	4·0
358	† ULVERSTON Rivet, Best.	,,	257	·4417	48,870	26·8	6·40	23·9	·62	1·00	1·62	2·44	3·90	
359	GLASGOW B. Best.	,,	744	·3116	58,671	22·4	3·88	17·3	·88	1·62	3·02			
360	◇ GOVAN. ◇	,,	725	·3116	60,558	22·4	4·80	21·4	·84	1·47	2·47			

–, OBSERVED.

M.

an-inch scale.

se marked *S.*, which were received from the Makers.

UNDER PROGRESSIVE STRAINS.																					
33,598	35,194	36,790	38,386	39,982	41,578	43,174	44,770	46,366	47,962	49,558	51,154	52,750	54,346	55,942	57,538	59,134	60,730	62,326	63,922	65,518	67,114
15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.
	·11		·25		·41		·60		·81		1·08		1·38		1·76		2·21	2·52	2·88	3·38	3·90
	·12		·20		·34		·50		·76		1·05		1·38		1·86		2·46	2·88	3·36	3·91	4·56
	·01		·03		·05		·10		·18		0·31		0·52		0·74		1·12	1·31	1·52	1·68	2·00
	·03		·17		·30		·48		·70		0·98		1·38	1·58	1·81	2·11	2·46	2·55	2·79	3·07	
	·28		·52		·83		1·28		1·78		2·33		3·03	3·48	3·88	4·38	5·28				
	·18		·33		·55		0·85		1·18		1·60	1·88	2·17	2·54	2·95	3·35	3·85				
	·24		·45		·70		1·05		1·45		2·15	2·35	3·00	3·35	3·90	4·20					
	·37		·65		1·07		1·50		2·15	2·63	3·10	3·65	4·25	5·00							
	·28		·44		0·70		1·08		1·50	1·76	2·05										
	·05		·10		0·20		0·37		0·61	0·78	0·98										
	·27		·52		0·90	1·22	1·52	1·80	2·10	2·38	2·67										
	·20		·40		0·77	0·94	1·30	1·72	2·17	2·90	3·50										
	1·10		1·42	1·68	1·95	2·35	2·95	3·50	4·25	5·20											
	1·37		1·90	2·27	2·64	3·04	3·62	4·24	5·82												
	1·05		1·50	1·80	2·15	2·60	3·15	3·70	4·35												
	0·67		1·03	1·30	1·65	2·05	2·40	2·95	3·85												
	0·97		1·55	1·96	2·30	2·67	3·20	3·93	4·75												
	0·60		1·00	1·35	1·72	2·18	2·80	3·50	4·10												
	0·52		0·92	1·18	1·52	2·00	2·60	3·20													
	1·13		1·60	1·96	2·30	2·67	3·05	3·75													
	1·18		1·92	2·35	2·65	3·40	4·00	5·20													
	0·85		1·47	1·77	2·10	2·65	3·37	4·35													
	0·73		1·15	1·65	1·97	2·53	3·25	4·17													
	1·19		1·87	2·35	2·95	3·69	4·72														
	1·40		2·25	2·77	3·55	4·45	5·30														
	1·55		2·25	2·75	3·22	4·70															
	1·15		1·75	2·30	3·00	3·75															
	1·20	1·47	1·80	2·27	2·90	3·77															
	1·83	2·16	2·70	3·33	3·94	4·88															
	1·37	1·79	2·13	2·71	3·36	4·11															
	1·72	2·23	2·88	3·68	5·15																
	2·15	2·55	3·42	4·00	4·82																
	1·40	1·75	2·25	2·95	3·80																
	1·73	2·25	2·95	3·75																	
2·98	3·75	4·50	6·05																		
1·70	2·20	2·82	3·48																		
3·00	3·76	4·60																			
2·08	2·78	3·85																			
1·88	2·42	3·18																			
1·80	2·32	3·20																			
5·20																					

RATE OF ELONGA

These and

The Measurements

Note.—All the pieces were taken *promiscuously* from Engineers' or

Reference No.	Names of the Makers or Works.	Description.	Index No. and Table.	Area of Specimen.	Ultimate Strength per sq. inch.	Ultimate Extension. Original.	Ultimate Extension. Increase.	Ultimate Extension. Per cent.	EXTENSION 11,422	12,990	14,548	16,116	17,684
				sq. in.	lbs.				1.	2.	3.	4.	5.
	TILTED BARS.												
361	† Russian C C ND.	Forged.	Table B. 277	·7088	56,447	24·0	1·60	6·6		..		..	
362	† ,, ,, I-O P S.	Tilted.	806	·6903	59,096	32·8	1·96	6·0		..		..	
363	,, ,, C C ND.	Forged.	276	·6504	65,516	24·0	2·28	9·5		..		..	
364	† Swedish R F.	,,	269	·6808	49,022	28·0	7·20	25·7		·07		·22	·31
365	,, ,, R F.	,,	271	·6362	46,869	28·0	6·88	24·6		·06		·23	·43
366	Russian I-O P S.	,,	810	·5674	51,466	32·0	2·40	7·5		·02		·12	·24
367	,, ,, C C ND.	Tilted.	272	·5073	55,190	24·0	2·32	9·7		·02		·10	·25
368	Swedish ꝏ C.	,,	805	·6600	42,421	26·8	4·08	15·2		·26		·47	·39
369	,, ,, R F.	,,	265	·5874	47,664	24·0	6·96	29·0		..		·18	·32
370	,, ,, R F.	,,	266	·5696	47,384	24·0	8·12	33·8		..		·25	·45
371	,, ,, ꝏ ꝏ W.	,,	804	.5888	43,509	30·8	4·72	15·3		..		·15	·40
372	,, ,, ꝏ C.	Forged.	808	·5674	41,251	32·0	4·72	14·8		..		·22	·50
373	,, ,, ꝏ ꝏ W.	,,	809	·4184	44,230	30·4	4·80	15·8	0·67	0·98	1·48	2·33	3·78
374	† ,, ,, OC.	,,	807	·3019	50,262	30·4	5·68	18·7	1·35	2·22	3·82		
375	,, ,, OC.	Tilted.	803	·3300	48,993	32·0	5·36	17·0	0·45	1·00	2·00		
	HAMMERED,												
376	† Armour-plate, cut cross &	Turned.	802	·7854	34,614	32·0	1·52	4·7		..		·02	
377	,, ,, ,, ,,	,,	801	·7854	36,646	32·0	2·20	6·9		..		·08	
378	† ,, ,, ,, ,,	,,	799	·7854	36,646	32·0	3·00	9·4		..		·20	
379	† Crank-shaft B, cut cross ,,	,,	794	·8171	40,124	32·0	2·64	8·3		..		..	
380	† ,, ,, length ,,	,,	783	·7854	44,561	26·0	4·56	17·6		..		..	
381	† ,, ,, length ,,	,,	788	·7854	43,420	26·0	6·40	24·6		..		..	
	MISCELLANEOUS.												
382	Crank-shaft A, cut cross, &	Turned.	Table N. 1099	·7854	48,375	26·0	3·48	13·4		..		..	
383	,, ,, ,, ,,	Forged.	1098	·7854	49,908	26·0	2·32	9·0		..		..	
381	,, ,, ,, ,,	,,	1097	·7854	50,906	26·0	2·40	9·3		..		..	
385	† ,, ,, ,, ,,	,,	1096	·7854	58,518	26·0	4·32	16·6		..		..	
386	† Govan Hammered-bar,	Turned. *S.*	1120	0·7854	64,133	32·0	8·60	26·9		..		..	
387	† ,, ,,	,, *S.*	1119	0·7854	71,798	30·8	6·20	20·1		..		..	
388	† ,, ,,	Square. *S.*	1118	1·0404	60,737	26·4	6·00	22·7		..		..	
389	† ,, ,,	,, *S.*	1117	1·0000	67,366	26·4	4·88	18·5		..		..	
390	† <> Govan. <> Rolled-bar.	*S.*	1113	1·2668	56,869	24·0	6·80	28·3		..		..	
391	† All cut off *one* bar 1½ in diam.,	*S.*	1114	0·8012	57,379	24·0	6·40	26·7		..		..	
392	† and after reheating rolled down	*S.*	1115	0·4417	58,190	24·0	6·04	25·2		·06		·34	·92
393	† to 1¼, 1, ¾, ½, to note the effects of additional rolling.	*S.*	1116	0·2124	59,708	24·0	5·72	23·8	2·58				
394	† Bowling, Forged, Cooled in Water.		1045	·6220	76,839	20·0	4·00	20·0		..		..	
395	,, ,, ,, Water.		1047	·5812	71,538	20·0	4·08	20·4		..		..	
396	,, ,, ,, Oil.		1048	·5945	65,934	20·0	3·60	18·0		..		..	
397	Bowling, Rolled-bar, Square.		1111	·5700	58,453	26·0	6·28	24·1		..		..	
398	Blochairn Best, Ordinary state.	*S.*	1090	·5310	60,637	22·0	5·00	22·8		..		..	
399	,, ,, Cold-rolled.	*S.*	1081	·4536	78,466	22·0	1·92	8·7		..		..	
400	,, ,, Do. & annealed.	*S.*	1088	·4657	62,285	22·0	5·52	25·0		..		..	
401	Glasgow B. Best, Case-hardened.		1059	·3848	60,317	16·0	2·04	12·7		..		·20	·45
402	Bowling ,, ,,		1062	·3958	54,537	16·0	1·44	9·0		..		·50	·75
403	Bowling ,, ,,		1061	·3526	57,274	16·0	1·68	10·5		..		·60	·90
	STEEL BARS.												
404	† Turtons' Cast-steel for	Chisels.	Table A. 1	·2207	145,383	10·4	0·56	5·4		..		..	
405	† Jowitt's ,, ,,	Chisels.	14	·2642	130,568	10·0	0·67	6·7		..		..	
406	† Jowitt's ,, ,,	Chisels.	15	·2642	121,340	10·0	0·72	7·2		..		..	
407	† Naylor & Co.'s ,, ,,	Rivets.	50	·4417	101,421	24·0	2·00	8·3		..		..	
408	† Moss & Gamble's ,, ,,	Rivets.	45	·4417	102,309	27·2	3·40	12·5		..		..	
409	† Naylor & Co.'s ,, ,,	Rivets.	47	·4417	112,262	24·0	2·20	9·2		..		..	
410	† Bessemer's Patent steel ,,	Tools.	29	·4300	113,588	27·2	1·60	5·9		..		..	
411	† Bessemer's ,, ,,	Tools.	27	·4417	123,165	27·2	1·66	6·1		..		..	
412	† Krupp's Cast-steel ,,	Bolts.	52	·6808	94,838	28·8	4·82	16·7		..		..	

.E L, OBSERVED.

r Table X.

rter of an inch scale.

ept those marked *S.*, which were received from the Makers.

UNDER PROGRESSIVE STRAINS.																							
27,21	28,810	30,406	32,002	33,598	35,194	36,790	38,386	39,982	41,578	43,174	44,770	46,366	47,962	49,558	51,154	52,750	54,346	55,942	57,538	59,134	60,730	62,326	63,922
1.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.
·28	·38	·52	·64	·74	·87	1·07	1·24	1·52															
·30	·40	·48	·63	·83	·98	1·16	1·46	1·73															
·21	·27	·38	·51	·67	·85	1·11	1·45																
·92	2·62	3·22																					
·00	4·18																						
·64	2·26																						
·17																							
·10																							
·10																							
·58																							
·05																							
·75	1·10	1·50	2·05																				
·08	1·40	1·82	2·38	3·10																			
·30	1·75	2·28	3·15	4·50																			
	·95		1·50	1·80	2·18	2·60																	
	·26		·55	·75	1·00	1·20	1·60																
	·40		·70	·90	1·15	1·45	1·75	2·20															
	·28		·55	·70	0·90	1·20	1·50	1·88	2·20	2·60	3·32												
	..		·92		1·40		2·18	2·45	3·20	3·62	3·90	4·48	5·60	7·22									
	..		·36		0·68		0·96		1·28		1·68	1·88	2·18	2·53	2·83	3·30	4·06						
	..		·14		0·34		0·70		0·90		1·14		1·52		1·84		2·40	2·64	3·10	3·50	4·10	4·82	
	..		·04		0·12		0·23		0·38		0·51		0·70		0·98		1·30		1·70	2·00	2·28	2·58	2·98
	..		·10		0·20		0·33		0·48		0·65		0·85		1·14		1·50		1·90		2·35	2·60	2·90
	·52		·87		1·32		2·00	2·40	2·88	3·72	4·84												
	..	·06	·18	·30	·50	0·62	0·75	1·00	1·20	1·50	1·90	2·35											
	·31	·42	·56	·73	·96	1·25	1·60	2·15															
·45	·60	·80	1·10	1·35	1·60	2·00	2·50																
·21	2·83	3·31	4·01																				
·52	1·97	2·60	3·82																				
·00	0·05																						
·85	3·85																						
37	·45																						
31	·38	·45	·52	·60																			
25	·30	·37	·50	·60																			
	·38		·49		·60		0·85	0·95	1·06														
	·55		·70		·90		1·17	1·30	1·60	1·90	2·13												
	·28		·34		·50		·67	·74	·84	1·02	1·14	1·34											
	·18		·30		·46		·58	·65	·79	·81	·95	1·14	1·40										
	·20		·30		·40		·50	·58	·60	·72	·80	0·91	1·05	1·18	1·30	1·46	1·66						
	·12		·28		·40		·56	·67	·76	·87	·98	1·12	1·29	1·45	1·62	1·88	2·10	2·37	2·68	3·03	3·40	3·83	4·45

RATE OF ELONGATI

These mark

The Measurements w

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Me

Reference No.		Names of the Makers or Works.		Length-Cross.	Index No. and Table.		Area of Specimen.	Ultimate Strength per sq. inch.	Ultimate Extension.			EXTENSION					
												14,548	16,116	17,684	19,252	20,830	22,4
							sq. in.	lbs.	Original.	Increase.	Per cent.	3.	4.	5.	6.	7.	8.
		STEEL PLATES.															
413	†	Turton & Son Cast.	S.	C.	306	Table C.	·536	98,519	22·4	2·76	12·3		..		..		..
414		Turton & Son Do.	S.	L.	302		·504	95,144	22·4	1·68	7·5		..		..		..
415	†	Mersey Coy. "Hard" Puddled.	S.	L.	356		·490	106,110	22·4	1·24	5·5		..		..		..
416	†	Blochairn Do.		L.	377		·624	97,413	30·4	2·04	6·7		..		..		..
417		Turton & Son Cast.	S.	C.	308		·500	92,788	22·4	1·32	5·9		..		..		..
418		Blochairn Puddled.		C.	380		·624	71,792	30·4	1·64	5·4		..		..		..
419	†	Shortridge & Co. Cast.		C.	336		·380	105,732	22·4	1·60	7·1		..		..		..
420		Shortridge & Co. Puddled.	S.	L.	342		·480	81,662	22·4	1·92	8·6		..		..		·13
421	†	Moss & Gamble Cast.	S.	L.	323		·476	79,937	22·4	4·40	19·7		..		..		·16
422	†	Moss & Gamble Do.	S.	C.	328		·521	71,796	22·4	4·40	19·7		..		..		·11
423	†	Shortridge & Co. Do.		L.	333		·378	97,328	22·4	1·32	5·9		..		..		·10
424	†	Shortridge & Co. Do.		L.	332		·360	101,105	22·4	1·08	4·8		..		..		·15
425	†	Blochairn Puddled.	S.	L.	371		·360	93,327	22·4	1·12	5·0		..		·22		·20
426		Blochairn Do.	S.	L.	375		·380	82,079	22·4	0·56	2·5		..		·02		·05
427	†	Blochairn Do.	S.	C.	376		·380	81,047	22·4	0·48	2·1		..		·06	·10	·15
428		Shortridge & Co., Hardened in Oil.		L.	1163	O.	·380	119,953	22·4	2·16	9·6		..		..		..
429		Blochairn, Do. Do.	S.	C.	1145		·380	128,426	22·4	0·36	1·6		..		..		..
430		Mersey Coy. Do. Do.	S.	L.	1155		·500	116,812	22·4	1·92	8·6		..		..		..
		IRON PLATES.															
431	†	Farnley.	S.	L.	438	Table D.	1·125	62,544	30·4	5·00	16·4		..		..		..
432	†	Farnley.	S.	C.	443		1·125	56,546	30·4	3·60	11·8		..		..		..
433	†	Consett Best Best.		L.	447		1·256	51,718	22·4	2·16	9·6		..		..		..
434		Bradley & Co.		L.	471		·995	60,697	22·4	2·32	10·4		..		..		..
435	†	Bradley ♔ S C.		L.	453		·960	58,534	22·4	3·52	15·7		..		..		..
436	†	Glasgow Best Best.		L.	579		·970	54,410	30·4	2·88	9·5		..		..		..
437	†	Glasgow Best Best.		L.	585		·988	52,229	30·4	3·20	10·7		..		..		..
438		Bradley ♔ S C.		L.	455		·995	53,889	22·4	2·32	10·4		..		..		..
439		Farnley.		L.	421		·750	59,443	30·4	4·12	13·5		..		..		..
440	†	◇ Govan. ◇		L.	970		·796	55,822	26·4	3·64	13·8		..		..		..
441	†	◇ Govan. ◇		C.	975		·826	52,303	26·4	1·80	6·8		..		..		..
442		Bradley L F.		L.	461		·772	55,925	22·4	2·72	12·1		..		..		..
443		Bradley & Co.		L.	472		·776	55,131	22·4	3·00	13·4		..		..		..
444	†	Lloyds, Foster, & Co.		C.	722		·906	46,789	30·4	1·44	4·7		..		..		..
445	†	Lloyds, Foster, & Co.		L.	716		·906	45,026	30·4	1·04	3·4		..		..		..
446		Glasgow Best Boiler.		L.	506		·750	54,907	22·4	1·88	8·4		..		..		..
447	†	Govan Best.		C.	547		·995	39,761	30·4	0·96	3·1		..		..		..
448		Govan Best.		L.	543		·995	38,570	30·4	0·96	3·1		..		..		..
449		Bowling.		L.	415		·750	51,443	22·4	3·12	13·9		..		·22		·34
450	†	Lowmoor.		L.	401		·624	57,881	22·4	3·36	15·0		..		·01		·18
451	†	Bowling.		L.	413		·650	51,991	22·4	2·76	12·3		..		·10		·30
452		K. B. M.		L.	491		·624	51,285	22·4	2·24	10·0		..		·03	·14	·26
453		Lowmoor.		L.	405		·624	47,426	22·4	2·16	9·6		..	·14	·26	·40	·56
454	†	Govan Best.		L.	544		·709	38,398	30·4	0·72	2·4		..	·02	·08	·15	·22
455		Blochairn B, Cold-rolled, annealed.		C.	1139	Table O.	·460	48,674	30·4	1·84	6·1		·10	·40	0·80	1·32	
456		Do. Do. Do.		L.	1136		·456	50,960	30·4	2·44	8·0		·40	·72	1·12	1·64	2·20
457		Do. Ordinary state.		L.	1137		·690	45,812	30·4	1·36	4·5		..		..		..
458		Do. Cold-rolled.		L.	1135		·476	88,993	30·4	0·04	0·1		..		..		..
		ANGLE-IRON, &c.															
459	†	Farnley.		L.	670	Table E.	·585	62,888	26·4	5·44	20·6	·02	·06	·10	·18	·28	·36
460	†	Albion Best.		L.	652		·932	52,363	30·4	4·40	14·5		..		..		..
461		Glasgow Best Best.		L.	637		·990	57,932	30·4	2·28	7·5		..		..		..
462		Consett.		L.	619		·946	54,103	30·4	2·00	6·6		..		..		..
463	†	Glasgow Best Best.		L.	634		·924	54,967	30·4	5·84	19·2		..		..		..
464	†	Glasgow Best Best.		L.	638		·986	53,527	30·4	1·60	5·3		..		..		..
465	†	Eagle.		L.	660		1·001	52,333	30·4	3·44	11·3		..		..		..
466	†	Eagle Best Best.		L.	658		1·025	54,250	30·4	4·00	13·1		..		..		..
467		Albion Best.		L.	654		1·053	52,807	30·4	3·52	11·6		..		..		..
468		Dundyvan.		L.	606		1·085	55,301	30·4	2·68	8·8		..		..		..
469		Glasgow Best Best.		L.	601		0·980	60,455	30·4	4·76	15·7		..		..		..
470		Glasgow Best Scrap.		L.	628		1·041	56,860	30·4	4·40	14·5		..		..		..
													..				

LE L, OBSERVED.

for Table M.

uarter-of-an-inch scale.

xcept those marked *S.*, which were received from the Makers.

UNDER PROGRESSIVE STRAINS.																							
30,406	32,002	33,598	35,194	36,790	38,386	39,982	41,578	43,174	44,770	46,366	47,962	49,558	51,154	52,750	54,346	55,942	57,538	59,134	60,730	62,326	63,922	65,518	67,114
13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.	33.	34.	35.	36.
	·30		·42		·60		·77	·89	1·02	1·20	1·42	1·72	2·12										
	·26		·35		·50		·65	·77	0·92	1·05	1·22	1·40	1·60										
	·14		·22		·35		·52	·60	0·69	0·79	0·90	1·00	1·25										
	·09		·16		·24	·30	·39	·48	0·55	0·65	0·77	0·90	1·05										
	·40		·52		·70	·79	·90	·99	1·15														
	·44	·53	·60	·70	·82	·95	1·15	1·45															
·52	·60	·71	·83	·99	1·19																		
·48	·66	·82	0·98	1·20	1·65																		
·75	·90	1·22	1·55	2·12																			
1·09	1·43	1·85	2·42	3·55																			
·55	0·70	0·90	1·15																				
·52	0·62	0·72	0·80																				
·90	1·05																						
·50																							
	·46		·60		·88		1·10	1·38	1·86														
	..		..		·15		0·19		0·24		0·31												
	..		..		·20		0·35		0·52		0·71		0·94		1·21		1·62						
	·10		·20		·32		·45		·62		0·82		1·12		1·48		1·88	2·12	2·38	2·68	2·94	3·20	3·75
	·10		·22		·37		·55		·75		1·00		1·30		1·73		2·15	2·33	2·77	3·10			
	·11		·15		·20		·26		·42		0·50		0·59		0·70	0·79	0·87	0·94	1·02	1·11			
	·14		·22		·33		·57		·79		1·00		1·26	1·40	1·55	1·75							
	·18		·28		·40		·60		·90		1·22	1·50	1·78	2·10	2·32	2·75							
	·08		·22		·38		·58		·92	1·12	1·42	1·70	2·12	2·72									
	·20		·43		·72		1·12		1·60	2·00	2·40	2·82											
	·26		·42		·66		0·95	1·10	1·30	1·60													
	·82		1·22	1·54	1·84	2·16	2·44	2·94	3·44														
	·34		0·95	1·17	1·47	1·82	2·27	2·72															
	·26		0·56	0·71	0·90	1·14	1·38																
	·75		1·12	1·40	1·70	1·95	2·32																
	·78		1·15	1·40	1·70	2·00	2·30																
	·17		0·37	0·51	0·75	0·97	1·20																
	·20		0·40	0·55	0·70	0·92																	
	·35	0·50	0·70	1·00	1·30																		
	·32	0·40	0·50	0·62	0·70																		
	0·35	0·48	0·60	0·74																			
1·08	1·22	1·63	1·90																				
1·20	1·60	2·10	2·50																				
1·45	2·00	2·55																					
1·35	1·72																						
1·10																							
0·00	·00	·00	·00	·01	·02	·03																	
1·68	2·20	2·90	3·72																				
	·45		·73	0·91	1·10	1·33	1·63	2·00	2·52	3·08	3·70												
	·01		·08		0·18		0·30	0·42	0·58	0·68	0·82												
	·09		·18		0·30		0·52	0·65	0·82	1·08	1·38	1·78											
	·42		·68		1·00		1·62	1·92	2·30	2·90	3·50	4·25											
	·01		·08		·20		0·38		0·65	0·78	0·92	1·15	1·40										
	·20		·42		·72		1·10		1·60	1·80	2·25	2·50	3·00										
	·35		·62		·92		1·22		1·60		2·00	2·20	2·35	2·90	3·42								
	·25		·37		·54		·82		1·13		1·60	1·82	2·08	2·43	2·70								
	·14		·20		·27		·35		0·60		0·88	1·01	1·23	1·40	1·61	1·87							
	·01		·10		·22		·42		0·68		1·01	1·21	1·46	1·70	2·02	2·38	2·78						
	·07		·17		·35		·57		0·89		1·25	1·48	1·80	2·01	2·35	2·82	3·40						

These marked

Note.—All the pieces were taken *promiscuously* from Engineers'

Reference No.		Names of the Makers or Works.	Description.	Table L, Reference No.	Index No. and Table.	Area of Specimen.	Extension per			
							26,000	28,000	30,000	32,000
				1.	2.	3.	4.	5.	6.	7.
		IRON BARS.								
501	‡	Lowmoor.	Forged.	343	Table B. 119	·5026	....	....	·0012	·0025
502	‡	Farnley.	Rolled.	315	129	·7854	....	....	·0045	·0060
503	‡	Bowling.	„	318	122	·7854	....	....	·0060	·0086
504		Lowmoor.	„	320	106	·7854	....	....	·0030	·0050
505	‡	Bradley ♛ S C	„	335	146	·6220	....	....	·0040	·0062
506	‡	Lowmoor. (square.)	Planed.	337	113	·6084	....	....	·0075	·0115
507	‡	Bowling.	Turned.	314	127	·7854	....	....	·0068	·0092
508		✱ Govan. ✱	Rolled.	311	201	·8498	....	....	·0000	·0003
509		Govan B. Best.	Rolled.	322	187	·7854	....	....	·0015	·0030
510	‡	Dundyvan.	Turned.	323	749	·7854	....	....	·0009	·0016
511		◇ Govan. ◇	Rolled.	316	721	0·8171	....	....	·0017	·0030
512	‡	Lowmoor. (square.)	„	305	103	1·0403	....	....	·0025	·0055
513		Bradley B. B. Scrap. S.	„	321	138	0·7854	....	....	·0030	·0046
514	‡	Russian IO P S	Tilted.	362	806	0·6903	....	....	·0008	·0014
515	‡	Coatbridge Best Rivet.	Rolled.	352	238	0·4417	....	....	·0010	·0020
516	‡	Dundyvan.	„	303	745	1·2271	....	....	·0006	·0011
517	‡	Bradley B. B. Scrap. S.	„	325	140	0·7854	....	....	·0004	·0028
518	‡	Ulverston Best Rivet.	„	354	253	0·4417	....	....	·0028	·0045
519		Malinslee ♛ Best.	„	338	297	0·7500	....	....	·0008	·0018
520	‡	Thorneycroft T N S	„	345	152	0·5153	....	....	·0038	·0070
521		Govan Ex. B. Best.	Rolled.	307	168	1·0387	....	....	·0029	·0059
522	‡	◇ Govan. ◇	Turned.	329	714	0·7854	....	....	·0068	·0092
523		◇ Govan. ◇	Forged.	328	718	0·7698	....	....	·0058	·0096
524		◇ Govan. ◇	Rolled.	301	711	1·2271	....	....	·0078	·0115
525	‡	Russian C C ND	Forged.	361	277	0·7088	....	....	·0044	·0056
526	‡	Bagnall ♛ J B	Turned.	330	706	0·7854	....	....	·0020	·0050
527	‡	Bradley Ⓛ S.	Rolled.	326	136	0·7854	....	....	·0036	·0070
528		Glasgow B. Best.	Turned.	324	734	0·8171	....	....	·0025	·0068
529		Glasgow B. Best.	Rolled.	302	730	1·2271	....	....	·0050	·0080
530	‡	Bradley ♛ S C	Rolled.	353	143	0·4417	....	....	·0062	·0094
531	‡	Bagnall ♛ J B	Rolled.	304	703	1·2271	....	...	·0035	·0080
532		✱ Govan. ✱	„	309	200	1·0387	....	....	·0056	·0080
533	‡	Swedish ƆC	Forged.	374	807	0·3019	....	....	·0200	·0252
534	‡	Swedish R F	„	364	269	0·6808	·0118	·0155	·0200	·0260
535	‡	Ulverston Best Rivet.	Rolled.	358	257	0·4417	·0049	·0083	·0182	·0193
536	‡	Crank-shaft B, cut out lengthway.	Turned.	380	783	0·7854	·0065	·0105	·0170	·0250
537	‡	Crank-shaft B, „ lengthway.	„	381	788	0·7854	·0085	·0150	·0230	·0320
538	‡	Crank-shaft B, „ crossway.	„	379	794	0·8171	·0049	·0078	·0125	·0185
539	‡	Armour-plate, „ crossway.	„	378	799	0·7854	·0192	·0260	·0340	·0450
540	‡	Armour-plate, „ crossway.	„	376	802	0·7854	·0085	·0130	·0190	·0270
541	‡	Crank-shaft A, cut-cross and forged.		385	Table O. 1096	0·7854	·0010	·0020	·0035	·0055
542	‡	◇ Govan. ◇ All cut off one bar, 1½ in. diameter, rolled down after reheating to 1¼, 1, ¾, ½ in., to note the effects of additional rolling. S.		390	1113	1·2668	·0050	·0092	·0140	·0188
543				391	1114	0·8012	·0030	·0058	·0090	·0125
544				392	1115	0·4417	....	....	....	....
545	‡			393	1116	0·2124	....	....	....	....
546		Govan Hammered-bar, (square.) S.		388	1118	1·0404	....	·0030	·0060	·0090
547	‡	„ „ „ (turned.)		386	1120	0·7854	....	·0055	·0078	·0100
548	‡	Do. Do. Do. (square.) S.		389	1117	1·0000	....	·0010	·0014	·0030
549	‡	„ „ „ (turned.)		387	1119	0·7854	....	·0035	·0050	·0070
550	†	Bowling, forged and cooled in water.		394	1045	0·6220	....	....	....	....

ale XII.

arked *S.*, which were received from the Makers.

ENGTH.—STRAIN IN LBS. PER SQUARE INCH OF (ORIGINAL) AREA.

44,000	46,000	48,000	50,000	52,000	54,000	56,000	58,000	60,000	62,000	64,000	66,000	Breaking	
												Exten.	Strain.
13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
0218	·0275	·0352	·0436	·0530	·0630	·0763	·0915	·1095	·1312	·1605		·2236	65,622
0338	·0412	·0518	·0630	·0750	·0900	·1050	·1245	·1490	·1860	·2500		·2647	64,133
0356	·0410	·0475	·0544	·0630	·0740	·0890	·1070	·1315	·1675			·2500	63,634
0310	·0400	·0500	·0600	·0705	·0840	·1000	·1185	·1420	·1960			·2583	62,635
0355	·0450	·0560	·0690	·0840	·1018	·1214	·1440	·1720	·2230			·2534	62,344
0432	·0520	·0605	·0695	·0810	·0960	·1138	·1332	·1565				·2253	61,805
0420	·0515	·0625	·0740	·0875	·1020	·1160	·1400	·1850				·2836	60,817
0168	·0235	·0310	·0405	·0522	·0650	·0780	·0915	·1075				·1130	60,722
0290	·0390	·0495	·0611	·0758	·0930	·1175	·1490	·2120				·2462	60,069
0190	·0260	·0345	·0460	·0595	·0760	·0970	·1230	·1750				·1813	60,069
0300	·0388	·0500	·0630	·0775	·0935	·1140	·1480					·2717	59,726
0462	·0574	·0697	·0825	·0986	·1160	·1355	·1636					·2362	59,390
0358	·0455	·0575	·0710	·0865	·1038	·1252	·1580					·2710	59,570
0152	·0190	·0232	·0280	·0335	·0400	·0465	·0538					·0598	59,096
0350	·0450	·0564	·0695	·0850	·1020	·1230	·1434					·1720	59,013
0165	·0228	·0304	·0395	·0500	·0610	·0736	·0912					·1000	58,640
0408	·0540	·0690	·0850	·1055	·1310	·1620	·2110					·2500	58,571
0295	·0385	·0490	·0630	·0780	·0990	·1315	·2060					·2060	58,000
0386	·0480	·0600	·0755	·0950	·1215	·1570						·2329	57,520
0408	·0510	·0638	·0786	·0965	·1210	·1580						·2081	57,431
0435	·0552	·0675	·0825	·0996	·1185	·1550						·2229	57,362
0570	·0700	·0850	·1015	·1205	·1470	·1920						·2500	57,003
0390	·0480	·0570	·0708	·0875	·1106	·1500						·2423	57,141
0478	·0580	·0700	·0840	·1020	·1285	·1750						·2472	56,701
0225	·0272	·0320	·0375	·0440	·0520	·0620						·0650	56,447
0420	·0540	·0670	·0830	·1000	·1250	·1840						·1840	56,005
0565	·0685	·0832	·0998	·1208	·1560	·2900						·2900	56,004
0460	·0570	·0720	·0890	·1112	·1430							·2133	55,761
0455	·0570	·0715	·0890	·1115	·1415							·1720	55,697
0450	·0580	·0740	·0922	·1170	·1550							·2088	55,463
0450	·0560	·0673	·0795	·0932	·1078							·1120	54,731
0418	·0518	·0625	·0755	·0890								·0914	52,348
0800	·1000	·1250	·1670									·1868	50,262
1142	·1480	·1940										·2570	49,022
0954	·1210	·1660										·2388	48,870
1480												·1754	44,561
												·2461	43,420
												·0825	40,124
												·0938	36,646
												·0475	34,614
320	·0420	·0530	·0645	·0770	·0925	·1125						·1662	58,518
695	·0840	·0998	·1170	·1386	·1670	·2200						·2833	56,869
552	·0680	·0820	·0995	·1200	·1560	·2065						·2666	57,379
582	·0715	·0858	·1030	·1250	·1500	·1850	·2400					·2517	58,190
448	·0543	·0655	·0780	·0925	·1105	·1355	·1750					·2375	59,708
455	·0550	·0638	·0760	·0910	·1092	·1218	·1505	·1880				·2273	60,737
410	·0490	·0580	·0680	·0800	·0940	·1110	·1320	·1565	·1930	·2550		·2688	64,133
180	·0225	·0278	·0336	·0406	·0480	·0576	·0680	·0820	·0980	·1150	·1426	·1848	67,366
218	·0255	·0292	·0340	·0390	·0450	·0515	·0590	·0675	·0765	·0808	·0985	·2013	71,798
010	·0024	·0040	·0070	·0110	·0150	·0205	·0260	·0326	·0405	·0488	·0580	·2000	76,839

RATE OF ELONGA

Those marked ‡ are Line

NOTE.—All the pieces were taken *promiscuously* from Engineers' or

Reference No.		Names of the Makers or Works.		Table I. Reference No.	Index No. and Table.		Area of Specimen.	Extension per uni			
								50,000	54,000	58,000	62,000
		STEEL BARS.		1.	2.		3.	4.	5.	6.	7.
551	‡	TURTONS' Cast-steel for Tools.		404	1	TABLE A.	·2207	....	....	....	....
552	‡	JOWITT'S „ Chisels.		405	14		·2042	....	....	....	....
553	‡	BESSEMER'S Patent Steel for Tools.	*S.*	411	27		·4417	....	....	....	·0055
554	‡	JOWITT'S Cast-steel for Chisels.		406	15		·2642	....	....	....	·0030
555	‡	BESSEMER'S Patent Steel for Tools.	*S.*	410	29		·4300	....	....	·0028	·0040
556	‡	NAYLOR & CO.'S Cast-steel for Rivets.		409	47		·4417	....	....	·0070	·0091
557	‡	MOSS & GAMBLES' „ Rivets.	*S.*	408	45		·4417	·0112	·0135	·0160	·0188
558	‡	NAYLOR & CO.'S „ Rivets.		407	50		·4417	·0078	·0100	·0120	·0140
559	‡	KRUPP'S „ Bolts.		412	52		·6808	·0125	·0170	·0218	·0278
		STEEL PLATES.									
560	‡	SHORTRIDGE & CO., Hardened in Oil.	*L.*	428	1163		·380	....	....	·0035	·0065
561	‡	MERSEY & CO., "Hard" Puddled.	*S. L.*	415	356	TABLE C.	·490	....	....	·0033	·0046
562	‡	SHORTRIDGE & CO., Cast.	*C.*	419	336		·380	....	....	·0080	·0100
563	‡	SHORTRIDGE & CO., Cast.	*L.*	424	332		·360	....	....	·0048	·0065
564	‡	TURTON & SON, Cast.	*S. C.*	413	306		·536	....	....	·0120	·0152
565	‡	BLOCHAIRN, Puddled.	*L.*	416	377		·624	....	....	·0065	·0088
566	‡	SHORTRIDGE & CO., Cast.	*L.*	423	333		·378	....	....	·0048	·0070
567		BLOCHAIRN, Puddled.	*S. L.*	425	371		·360	·0038	·0060	·0092	·0130
568		BLOCHAIRN, Puddled.	*S. C.*	427	376		·380	·0024	·0040	·0060	·0082
569	‡	MOSS & GAMBLES, Cast.	*S. L.*	421	323		·476	·0110	·0162	·0222	·0295
570	‡	MOSS & GAMBLES, Cast.	*S. C.*	422	328		·521	·0202	·0318	·0480	·0688
		IRON PLATES.						26,000	28,000	30,000	32,000
571	‡	FARNLEY	*S. L.*	431	438	TABLE D.	1·125	·0018	·0030	·0050	·0070
572	‡	BRADLEY ♔ S C	*L.*	435	453		0·960	·0014	·0032	·0045	·0068
573	‡	LOWMOOR.	*L.*	450	401		0·624	....	....	·0000	·0018
574	‡	FARNLEY.	*S. C.*	432	443		1·125	·0018	·0031	·0058	·0088
575	‡	◇ GOVAN ◇	*L.*	440	970		0·796	·0006	·0017	·0032	·0056
576	‡	GLASGOW Best Best.	*L.*	436	579		0·970	....	....	·0018	·0033
577		◇ GOVAN ◇	*C.*	441	975		0·826	....	....	·0020	·0036
578	‡	GLASGOW Best Best.	*L.*	437	585		0·988	·0006	·0018	·0039	·0069
579	‡	BOWLING.	*L.*	451	413		0·650	·0009	·0026	·0051	·0088
580	‡	CONSETT Best Best.	*L.*	433	447		1·256	·0048	·0062	·0085	·0110
581		LLOYDS, FOSTER, & CO.	*C.*	444	722		0·906	....	....	·0005	·0017
582		LLOYDS, FOSTER, & CO.	*L.*	445	716		0·906	....	....	·0018	·0031
583		GOVAN Best.	*C.*	447	547		0·995	·0038	·0058	·0080	·0108
584		GOVAN Best.	*L.*	454	544		0·709	·0019	·0035	·0056	·0080
		ANGLE-IRON.									
585	‡	FARNLEY.		459	670	TABLE E.	0·585	·0011	·0028	·0042	·0060
586	‡	GLASGOW Best Best.		463	634		0·924	·0005	·0022	·0050	·0090
587	‡	EAGLE Best Best.		466	658		1·025	·0000	·0030	·0080	·0132
588	‡	GLASGOW Best Best.		464	638		0·986	·0000	·0000	·0000	·0000
589	‡	ALBION Best.		460	652		0·932	·0008	·0028	·0053	·0090
590	‡	EAGLE.		465	660		1·001	·0005	·0017	·0035	·0070

LE M, REDUCED.

am-Plates XI.-XIII.

:cept those marked S., which were received from the Makers.

THE LENGTH.—STRAIN IN LBS. PER SQUARE INCH OF (ORIGINAL) AREA.														Breaking	
78,000	82,000	86,000	90,000	94,000	98,000	102,000	106,000	110,000	114,000	118,000	122,000	126,000	130,000	Exten.	Strain.
11.	12.	13.	14.	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.
011	·0027	·0049	·0070	·0098	·0125	·0151	·0185	·0220	·0260	·0300	·0340	·0381	·0421	·0538	145,383
118	·0150	·0180	·0210	·0240	·0270	·0308	·0345	·0388	·0432	·0481	·0532	·0595	·0652	·0670	130,568
142	·0165	·0190	·0215	·0240	·0271	·0308	·0350	·0400	·0452	·0517	·0580			·0610	123,165
176	·0212	·0251	·0290	·0330	·0376	·0425	·0476	·0542	·0595	·0660				·0720	121,340
138	·0160	·0186	·0210	·0236	·0270	·0316	·0392	·0478						·0588	113,588
197	·0228	·0260	·0300	·0350	·0410	·0494	·0600	·0772						·0917	112,262
315	·0360	·0420	·0481	·0570	·0730	·1115								·1250	102,309
240	·0286	·0330	·0390	·0470	·0605									·0833	101,421
660	·0820	·1009	·1230	·1560										·1673	94,838
152	·0180	·0210	·0240	·0278	·0320	·0373	·0428	·0508	·0626	·0820				·0964	119,953
152	·0200	·0245	·0293	·0340	·0400	·0462	·0540							·0554	106,110
220	·0258	·0290	·0330	·0389	·0460	·0564								·0714	105,732
176	·0211	·0252	·0298	·0345	·0410									·0482	101,105
350	·0426	·0521	·0665	·0855	·1162									·1232	98,519
278	·0334	·0400	·0483	·0578										·0671	97,413
218	·0280	·0350	·0435	·0535										·0643	97,328
292	·0348	·0408	·0480											·0550	93,327
192														·0214	81,047
1160														·1964	79,937
														·1964	71,797
40,000	42,000	44,000	46,000	48,000	50,060	52,000	54,000	56,000	58,000	60,000	62,000	64,000	66,000		
0205	·0260	·0322	·0396	·0477	·0570	·0675	·0800	·0920	·1060	·1242	·1500			·1645	62,544
0180	·0228	·0290	·0370	·0458	·0574	·0710	·0855	·1055	·1370					·1571	58,534
0190	·0258	·0330	·0417	·0510	·0630	·0760	·0922	·1135						·1500	57,881
0255	·0315	·0381	·0460	·0550	·0655	·0778	·0920	·1110						·1184	56,546
0209	·0270	·0348	·0441	·0550	·0676	·0822	·1040							·1379	55,822
0137	·0181	·0240	·0310	·0391	·0500	·0646	·0876							·0947	54,410
0142	·0192	·0252	·0330	·0416	·0515	·0655								·0682	52,303
0279	·0370	·0478	·0605	·0745	·0892	·1050								·1073	52,229
0309	·0397	·0500	·0611	·0744	·0923									·1232	51,991
0240	·0288	·0335	·0390	·0450	·0520									·0690	51,718
0151	·0218	·0302	·0420											·0474	46,789
0170	·0230	·0302												·0342	45,026
														·0310	39,761
														·0237	38,398
0188	·0238	·0298	·0370	·0448	·0542	·0655	·0800	·0955	·1133	·1370	·1750			·2061	62,888
0286	·0362	·0468	·0582	·0740	·0930	·1170	·1544							·1921	54,967
0383	·0455	·0531	·0630	·0722	·0840	·1005	·1280							·1315	54,250
0080	·0121	·0170	·0230	·0300	·0378	·0456								·0526	53,527
0320	·0410	·0515	·0650	·0830	·1042	·1362								·1456	52,363
0280	·0375	·0480	·0605	·0740	·0900	·1090								·1131	52,333

Representations of the

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchants'

Index No.	Names of the Makers or Works.	How Treated.		Original	
				Diamt.	Area.
	STEEL BARS.			1. inch.	2. sq. in.
1001	Jowitt's Cast-steel for Chisels.	Highly heated and cooled in Oil.	Off 1 Bar	·57	·2552
1002	„ „ „	„ „ Water.		·62	·3019
1003	„ „ „	„ „ „ Yellow temper.		·56	·2462
1004	„ „ „	„ „ „ Spring „		·62	·3019
1005	„ „ „	„ „ „ Blue „		·56	·2463
1006	„ „ „	„ „ Ashes, slowly.		·60	·2827
1007	Do. Do. Do.	Medium heat Do. Do. Oil.	1 Bar	·57	·2552
1008	„ „ „	„ „ Tallow.		·59	·2734
1009	„ „ „	„ „ Coal Tar.		·62	·3019
1010	„ „ „	„ „ Slowly.		·62	·3019
1011	Do. Do. Do.	Low heat Do. Do. Oil.	1 Bar	·57	·2552
1012	„ „ „	„ „ Tallow.		·60	·2827
1013	„ „ „	„ „ Coal Tar.		·59	·2734
1014	„ „ „	„ „ Slowly.		·60	·2827
1015	Do. Do. Do.	High heat Do. Do. Oil.	1 Bar	·60	·2827
1016	„ „ „	Low „ „ Oil.		·59	·2734
1017	„ „ „	Low „ „ Tallow.		·56	·2734
1018	„ „ „	High „ „ Slowly.		·62	·3019
1019	Bessemer's Patent Steel for Tools. S.	Heated and cooled in Oil.	{	·63	·3116
1020	„ „ „	„ „ Slowly.		·75	·4417
1021	Do. Do. Do. S.	Do. Do. Oil.	{	·64	·3216
1022	„ „ „	„ „ Slowly.		·66	·3318
1023	Do. Do. Do. S.	Do. Do. Oil.	{	·65	·3318
1024	„ „ „	„ „ Slowly.		·74	·4300
1025	Naylor & Co.'s Cast-steel for Rivets.	Heated and cooled in Oil.	{	·60	·2827
1026	„ „ „	„ „ Slowly.		·75	·4417
1027	Do. Do. Do.	Do. Do. Oil.	{	·62	·3019
1028	„ „ „	„ „ Slowly.		·75	·4417
1029	Moss & Co.'s Cast-steel for Rivets. S.	Heated and cooled in Oil.	{	·62	·3019
1030	„ „ „	„ „ Slowly.		·75	·4417
1031	Do. Do. Do. S.	Do. Do. Oil.	{	·62	·3019
1032	„ „ „	„ „ Slowly.		·75	·4417
1033	Do. Do. Do. S.	Do. Do. Oil.	{	·64	·3216
1034	„ „ „	„ „ Slowly.		·75	·4417
1035	Do. Do. Do. S.	Do. Do. Water.	{	·63	·3116
1036	„ „ „	„ „ Slowly		·75	·4417
1037	Shortridge & Co.'s Hom. Metal.	Highly heated and cooled in Oil.	Off 1 Bar	·60	·2827
1038	„ „ „	Medium „ „ Oil.		·60	·2827
1039	„ „ „	Low „ „ Oil.		·60	·2827
1040	„ „ „	Low „ „ Oil.		·61	·2922
1041	„ „ „	High „ „ Slowly.		·62	·3019
1042	„ „ „	High „ „ Water.		·62	·3019
1043	Mersey Co.'s Rivet Steel.	Heated and cooled Slowly.		·43	·1452
1044	„ „ „	„ „ Slowly.		·37	·1075
	IRON BARS.				
1045	Bowling.	Highly heated and cooled in Water.	Forged	·89	·6220
1046	„	„ „ Water.		·87	·5945
1047	„	„ „ Water.		·86	·5811
1048	„	„ „ Oil.		·87	·5945
1049	„	„ „ Oil.		·72	·4071
1050	„	„ „ Tar.		·70	·3848

TREATMENT. TABLE N, BARS.

Fractures in Plates II., V.

Stores, except those marked *S*., which were received from the Makers.

Weight on Steel-Yard.	Breaking Weight per Square Inch.	FRACTURED,		Difference between *Original & Fractured* Areas.		ELONGATION,			FRACTURE.	
		Diamt.	Area.			Original length of stretched part in column 10.			Granular.	Kind.
3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
lbs.	lbs.	inch.	sq. in.	sq. in.	℔ cent.	inch.	inches.	℔ cent.	℔ cent.	
1675	215,400	·56	·2462	·0090	3·5	·10	3·0	3·3	100	A
647	90,049	·62	·3019	·0000	0·0	·00	"	0·0	100	A
564	100,983	·56	·2462	·0000	0·0	·00	"	0 0	100	A
807	104,888	·62	·3019	·0000	0·0	·02	"	0·7	100	A
734	112,119	·58	·2642	·0000	0·0	·02	"	0·7	100	A
905	121,716	·56	·2462	·0365	12·9	·21	"	7·0	100	A B
1362	184,977	·56s	·2462	·0090	3·5	·08	3·0	2·7	100	C
1419	178,500	·58	·2642	·0092	3·4	·08	"	2·7	100	A
1477	167,028	·60	·2827	·0192	6 4	·18	"	6·0	100	A
961	119,172	·59	·2734	·0285	9·4	·23	"	7·7	100	A B
1163	163,142	·55s	·2376	·0176	6·8	·15	3·0	5·0	100	C
1133	144,301	·58s	·2642	·0185	6·6	·21	"	7·0	100	C
1062	141,940	·55	·2376	·0358	13·1	·26	"	8·7	100	A B
948	125,978	·55	·2376	·0451	16·5	·30	"	10·0	100	A B
1592	189,763	·59	·2734	·0093	3·3	·10	3·0	3·3	100	A
962	131,697	·57	·2552	·0182	6·6	·28	"	9·3	100	A
777	112,750	·50	·1963	·0771	28·2	·54	"	18 0	95	B I
819	106,002	·54	·2290	·0729	24·1	·45	"	15·0	100	B
2025	211,072	·63	·3116	·0000	0·0	·04	4·0	0·1	100	A
1619	123,165	·72s	·4071	·0346	7·8	·40	6·8	5·9	100	B C
1904	193,974	·64	·3216	·0000	0·0	·03	4·0	0·1	100	A
1077	118,221	·63s	·3116	·0202	6·1	·18	6·8	2·7	100	B C
1790	178,390	·64s	·3216	·0102	3·1	·10	4·0	0·2	100	A C
1420	113,588	·59	·2734	·1566	36·4	·53	6·8	7·8	90	B I
1675	185,392	·58	·2642	·0185	6·5	·14	4·0	3·5	100	A B
1447	112,262	·60	·2827	·1590	36·0	·55	6·0	9·2	85	F I
1618	180,106	·60	·2827	·0192	6·3	·10	4·0	2·5	100	A B
1276	101,421	·62	·3019	·1398	31·6	·50	6·0	8·3	90	F
1562	174,912	·61s	·2922	·0097	3·2	·24	4·0	6·0	100	B
1291	102,309	·60	·2827	·1590	36·0	·85	6·8	12·5	50	F I
1447	164,246	·53	·2207	·0812	26·9	·46	4·0	11·5	85	F I
1518	116,763	·63	·3116	·1301	29·4	·80	6·8	11·8	90	F
1461	155,404	·55	·2376	·0840	26·1	·40	4·0	10·0	82	F I
1276	101,422	·59	·2734	·1683	52·3	·88	6·8	12·0	0	I
590	82,124	·63	·3116	·0000	0·0	·02	4 0	0·0	100	A
1319	108,649	·63	·3116	·1301	29·4	·85	6·8	12·5	76	F
991	130,237	·58s	·2642	·0185	6·5	·10	4·0	2·5	95	F
877	118,946	·55	·2376	·0451	16·0	·44	3·0	14·7	30	F I
635	94,977	·50	·1963	·0864	30·5	·57	2·8	20·4	30	F I
635	91,890	·50	·1963	·0959	32·7	·60	2·8	21·4	0	I
562	82,166	·49	·1885	·1134	37·5	·55	2·5	22·0	0	I
398	66,953	·62	·3019	·0000	00·0	·03	2·5	0·0	100	A
165	94,284	·37	·1078	·0374	25·8	·64	8·0	8·0	12	F I
28	91,410	·28	·0616	·0462	42·7	·78	8·0	9·8	0	I
									Crystalline.	
1383	76,839	·72	·4071	·2149	34·5	1·00	5 0	20·0	0	P
1204	71,963	·75	·4417	·1528	25·7	0·92	"	18·4	0*r*	P
1161	71,538	·64	·3216	·2596	44·7	1·02	"	20·4	0	P
1076	65,934	·75	·4417	·1528	25·7	0·90	"	18·0	0	P
597	63,341	·55	·2376	·1695	41·6	1·08	"	21·6	0	P
540	62,864	·54	·2290	·1558	40·5	1·12	"	22·4	2	P

Representatio

Note.—All the pieces were taken *promiscuously* from Engineers' or M

Index No.	Names of the Makers or Works.		How Treated.		ORIGI
					Diam.
	IRON BARS.				1. inch.
1051	Bradley & Co. Ⓛ	*S.*	Case-hardened in furnace, *a*, cooled in Oil.	Inch Bars Forged down	·74
1052	" "	*S.*	" " *a*, " Water.		·77
1053	Bradley B. B. Scrap.	*S.*	Do. Do. *a*, Do. Oil.		·77
1054	" "	*S.*	" " *a*, " Water.		·75
1055	Lowmoor.		Do. Do. *a*, Do. Oil.		·75
1056	"		" " *a*, " Water.		·74
1057	Glasgow B. Best.		Do. Do. *a*, Do. Oil.		·73
1058	" "		" " *a*, " Water.		·72
1059	Glasgow B. Best.		Do. Do. *b*, Do. Slowly.		·70
1060	" "		" " *c*, " "		·60
1061	Bowling.		Do. Do. *b*, Do. Slowly.		·67
1062	"		" " *c*, " "		·71
1063	Bradley B. B. Scrap.	*S.*	Do. Do. *d*, Do. Do.	Inch Bars Turned down	·87
1064	" "	*S.*	" " *f*, " "		·88
1065	Bowling.		Do. Do. *e*, Do. Do.		·87
1066	"		" " *f*, " "		·89
1067	"		" " *d*, " "		·87
1068	"		" " *f*, " "		·88
1069	Port-Dundas Ex. B. Best.		Do. Do. *e*, Do. Do.		·88
1070	" "		" " *d*, " "		·87
1071	" "		" " *f*, " "		·88
1072	" "		" " *f*, " "		·88
1073	Blochairn B. Best.		Do. Do. *e*, Do. Do.		·87
1074	" "		" " *f*, " "		·88
1075	" "		" " *d*, " "		·87
1076	" "		" " *f*, " "		·88
1077	Dundyvan.		Do. Do. *e*, Do. Do.		·88
1078	"		" " *e*, " "		·88
1079	"		" " *d*, " "		·87
1080	"		" " *f*, " "		·88
1081	Blochairn Best. Off one Bar.	*S.*	"Cold-rolled" at the Works by Mr. Lauth.		·76
1082			" " "		·76
1083			" " "		·76
1084			" " "		·76
1085			" " "		·76
1086			" " "		·77
1087			" " "		·77
1088			Do. Do. and annealed.		·77
1089			" " "		·76
1090			In the ordinary condition.		·83
1091	Glasgow B. Best. Off one Bar.		In the ordinary condition, & temperature 64°.		·75
1092			Exposed all night to intense frost, and broken in the morning; thermometer at 23° Fah. (Refer to Table T. 1536-1542.)		·75
1093					·75
1094	Glasgow B. Best. Off one Bar.		In the ordinary condition.		·75
1095			Brought to a "welding heat," and cooled slowly without being hammered.		·73

ATMENT. TABLE N, BARS.

es in Plates II., V.

except those marked *S*, which were received from the Makers.

Breaking Weight per Square Inch.	FRACTURED,		Difference between *Original & Fractured* Areas.		ELONGATION,			FRACTURE.	
	Diamt.	Area.			Original length of stretched part in column 10.			Granular & Crystalline.	Kind.
4.	5.	6.	7.	8.	9.	10.	11.	12.	13.
lbs.	inch.	sq. in.	sq. in.	℘ cent.	inch.	inches.	℘ cent.	℘ cent.	
55,800	·73	·4184	·0116	2·7	·17	4·0	4·2	100	k
51,522	·77	·4657	·0000	0·0	·11	4·0	2·7	100	**k**
56,693	·76	·4536	·0121	2·6	·20	4·0	5·0	100	k
52,547	·75	·4417	·0000	0.0	·12	4·0	3·0	100	k
59,583	·74	·4300	·0117	2·7	·25	4·0	6·2	50*r*	m o
57,167	·74	·4300	·0000	0·0	·14	4·0	3·5	94*r*	m o
55,473	·71	·3958	·0226	5·4	·38	4·0	9·5	40	**o**
51,236	·72	·4071	·0000	0·0	·10	4·0	2·5	95	m o
60,317	·66	·3421	·0427	11·1	·51	4·0	12·7	20	o
55,161	·57	·2552	·0275	9·7	·56	4·0	14·0	20	o
57,274	·64	·3216	·0310	8·8	·42	4·0	10·5	100	m
54,537	·68	·3632	·0326	8·2	·36	4·0	9·0	100	m
51,084	·85	·5674	·0271	4·6	·33	4·0	8·2	95	l
48,060	·87	·5945	·0137	2·2	·13	4·0	3·2	100	**l**
59,340	·84	·5441	·0504	8·5	·47	4·0	11·7	100	m
55,276	·87	·5945	·0275	4·4	·28	4·0	7·0	100	m
51,449	·85	·5674	·0271	4·6	·26	4·0	6·5	100	m
51,282	·87	·5945	·0137	2·2	·12	4·0	3·0	100	**m**
58,004	·83	·5310	·0772	12·7	·65	5·0	13·0	100	m n
47,245	·86	·5812	·0133	2·3	·20	5·0	4·0	100	m n
39,451	·88*s*	·6082	·0000	0·0	·06	5·0	1·2	68*r*	n o
39,451	·88*s*	·6082	·0000	0·0	·03	5·0	0·6	100*r*	m n
53,468	·85	·5674	·0271	4·6	·40	5·0	8·0	100	m n
49,395	·87	·5945	·0137	2·2	·17	5·0	3·4	100	m n
47,950	·87*s*	·5945	·0000	0·0	·11	5·0	2·2	100	n
47,370	·88	·6082	·0000	0·0	·07	5·0	1·4	100	n
57,267	·86	·5812	·0270	4·4	·43	5·0	8·6	100	n
48,750	·87	·5945	·0137	2·2	·15	5·0	3·0	100*r*	n
47,245	·87	·5945	·0000	0·0	·10	5·0	2·0	100*r*	n
39,451	·88	·6082	·0000	0·0	·03	5·0	0·6	100	**n**
								Crystalline.	
78,466	·65	·3318	·1218	26·8	0·48	5·5	8·7	0	**p**
72,341	·61	·2922	·1614	35·6	0·59	5·5	10·7	0	p q
70,551	·60	·2827	·1709	37·7	0·66	5·5	12·0	0	p q
70,551	·60	·2827	·1709	37·7	0·66	5·5	12·0	0	p q
70,551	·60	·2827	·1709	37·7	0·68	5·5	12·4	0	p q
68,718	·60	·2827	·1830	39·3	0·71	5·5	13·0	0	p q
68,718	·60	·2827	·1830	39·3	0·76	5·5	13·8	0	p q
62,285	·57	·2552	·2105	45·2	1·38	5·5	25·0	0	**q**
56,477	·55	·2376	·2160	47.6	1·44	5·5	26·2	0	q
60,637	·62	·3019	·2291	43·1	1·25	5·5	22·8	0	q
55,717	·56	·2462	·1955	44·2	1·37	5·5	24·9	0	q
54,385	·59	·2734	·1683	38·1	1·24	5·5	22·5	0	q
54,385	·58	·2642	·1775	40·2	1·30	5·5	23·6	0	q
56,604	·57	·2552	·1865	42·2	1·45	6·5	22·3	2	q
56,477	·62	·3019	·1165	27·8	1·15	6·5	17·7	18	

EFFECTS OF DIFFERENCE I

Represent

NOTE.—All the pieces were taken *promiscuously* from Engineers' s

Index No.	Names of the Makers or Works, and how Treated.	ORIGINAL, Diameter.	ORIGINAL, Area.	Weight on Steel-Yard.
		1.	2.	3.
		inch.	sq. in.	lbs.
1096	Crank-shaft (A) cut out crossway and forged down.	1·00	·7854	1319
1097	,, ,, ,,	1·00	·7854	1104
1098	,, ,, ,,	1·00	·7854	1076
1099	Do. Do. turned down; heated and cooled slowly.	1·00	·7854	1033
1100	Do. Do. heated and cooled in water.	1·00	·7854	476
1101	Crank-shaft (B) cut length, heated and cooled in water.	1·00	·7854	1147
1102	Do. Do. without being heated.	1·00	·7854	919
1103	Armour-plate cut cross, heated and cooled in water.	1·00	·7854	705
1104	,, ,, ,, ,,	1·00	·7854	690
1105	Do. Do. without being heated.	1·00	·7854	647
1106	GOVAN B. Best Rolled-bar. 1st Trial. 2d ,, The collars of these bolts having come off at the first trial, they were replaced and tested, to observe the effects of re-heating, &c.	1·12	·9852	1831 1704
1107	LOWMOOR Do. 1st Trial. 2d ,,	1·00	·7854	1919 1340
1108	LOWMOOR Do. 1st Trial. 2d ,,	1·01	·8012	1378 1318
1109	FARNLEY Do. 1st Trial. 2d ,,	1·00	·7854	1304 1289
1110	FARNLEY Do. 1st Trial. 2d ,,	1·00	·7854	1247 990
1111	BOWLING Do. Square, ordinary state.	·76 × ·75	·5700	866
1112	,, ,, ,, ,,	·76 × ·65	·4940	705
1113	◈ GOVAN ◈ Rolled-bar. All cut off *one* Bar 1½ inch diameter, and after reheating, rolled down to 1¼, 1, ¾, ½, to note the effects of additional rolling. S.	1·27	1·2668	2249
1114	S.	1·01	0·8012	1318
1115	S.	0·75	0·4417	594
1116	S.	0·52	0·2124	129
1117	GOVAN Hammered-bar Square, 1 inch. S.	1·00 × 1·00	1·0000	2082
1118	,, ,, ,, ,, S.	1·02 × 1·02	1·0404	1932
1119	Do. Do. Turned down from 1¼ in. sq. S.	1·00	0·7854	1690
1120	,, ,, ,, ,, S.	1·00	0·7854	1475

res in Plates II., V.

except those marked *S.*, which were received from the Makers.

ACTURED,		Difference between *Original & Fractured* Areas.		ELONGATION,			FRACTURE.	
ter.	Area.			Original length of stretched part in column 10.			Crystalline.	Kind.
	6.	7.	8.	9.	10.	11.	12,	13,
	sq. in.	sq. in.	⅌ cent.	inch.	inches.	⅌ cent.	⅌ cent.	
	·6504	·1350	17·2	1·08	6·5	16·6	40	i
	·7238	·0616	7·9	0·60	6·5	9·3	50	i
	·7088	·0766	9·8	0·58	6·5	9·0	54	i
	·6504	·1350	17·2	0·87	6·5	13·4	35	c
	·7854	·0000	00·0	0·02	6·5	0·3	100	g
	·6362	·1492	19·0	1·08	6·5	16·6	15	h
	·5945	·1909	24·3	1·34	6·5	20·6	22	c
	·7543	·0311	4·0	0·20	8·0	2·5	32	cf
	·7543	·0311	4·0	0·24	8·0	3·0	18	cf
	·7392	·0462	5·9	0·38	8·0	4·8	0	f
	·8992	·0860	8·7	1·08	8·0	13·5	28	U
	·5281	·4571	46·4	2·71	8·0	33·9		
	·7392	·0462	5·9	0·58	7·5	7·7	0	P
	·3526	·4328	55·1	2·31	7·5	30·8		
	·7392	·0620	7·7	0·78	7·0	11·1	0	P
	·3526	·4486	56·0	2·58	7·0	36·9		
	·7543	·0311	4·0	0·51	7·0	7·3	0	P
	·3526	·4328	55·1	2·18	7·0	31·1		
	·6362	·1492	19·0	0·78	7·0	11·1	0	P
	·2922	·4932	62·8	2·14	7·0	30·6		
·50	·2550	·3150	55·3	1·57	6·5	24·1	0	N
·48	·2640	·2300	46·6	1·00	6·5	15·4	0	N
	·6362	·6306	49·78	1·70	6·0	28·3	0	P
	·4071	·3941	49·19	1·60	6·0	26·7	0	P
	·2210	·2207	49·98	1·51	6·0	25·2	0	P
	·1077	·1047	49·29	1·43	6·0	23·8	0	P
·77	·5929	·4071	40·7	1·22	6·6	18·5	0	r
·75	·5625	·4779	45·9	1·50	6·6	22·7	0	r
	·4657	·3197	40·7	1·55	7·7	20·1	0	r
	·4071	·3783	48·1	2·15	8·0	26·9	0	r

Representations

NOTE.—All the pieces were taken *promiscuously* from Engineers' or

Index No.	Names of the Makers or Works, and how Treated.	ORIGINAL, Thick. Bdth	ORIGINAL, Area.	Weight on Steel-Yard.
		1. inch.	2. sq. in.	3. lbs.
	IRON PLATES.			
1121	GLASGOW Best Boiler. Ordinary. L.	·186 × 2·00	·372	253
1122	,, ,, Galvanised. L.	·186 × ,,	·372	281
1123	,, ,, Ordinary. C.	·190 × ,,	·380	302
1124	,, ,, Galvanised. C.	·190 × ,,	·380	295
1125	Do. Do. Ordinary. L.	·235 × ,,	·470	379
1126	,, ,, Galvanised. L.	·235 × 1·90	·446	337
1127	,, ,, Ordinary. C.	·238 × 2·00	·476	281
1128	,, ,, Galvanised. C.	·238 × ,,	·476	337
1129	Do. Do. Ordinary. L.	·375 × ,,	·750	704
1130	,, ,, Galvanised. L.	·375 × ,,	·750	747
1131	,, ,, Ordinary. C.	·375 × ,,	·750	533
1132	,, ,, Galvanised. C.	·375 × ,,	·750	505
1133	Do. Do. Ordinary. C.	·186 × ,,	·372	280
1134	,, ,, Galvanised. C.	·186 × 1·90	·353	197
1135	BLOCHAIRN Best. Cold-rolled at Works by Mr. Lauth. S. L.	·238 × 2·00	·476	1189
1136	,, ,, Do., and then annealed. S. L.	·228 × ,,	·456	506
1137	,, ,, Ordinary state. S. L.	·345 × ,,	·690	805
1138	Do. Do. "Cold-rolled." S. C.	·238 × ,,	·476	1047
1139	,, ,, Do., and then annealed. S. C.	·230 × ,,	·460	476
1140	,, ,, Ordinary state. S. C.	·345 × ,,	·690	733
	STEEL PLATES.			
1141	BLOCHAIRN Puddled Steel, heated and cooled in Oil. S.	·190 × 2·00	·380	1475
1142	,, ,, Soft.	,, × ,,	·380	1061
1143	Do. Do. Do. Do. in Oil. S.	,, × ,,	·380	1475
1144	,, ,, Soft.	,, × ,,	·380	890
1145	Do. Do. Do. Do. in Oil. S.	,, × ,,	·380	1419
1146	,, ,, Soft.	,, × ,,	·380	790
1147	Do. Do. Do. Do. in Oil. S.	,, × ,,	·380	1304
1148	,, ,, Soft.	,, × ,,	·380	1120
1149	Do. Do. Do. Do. in Oil. S.	,, × ,,	·380	1247
1150	,, ,, Soft.	,, × ,,	·380	776
1151	Do. Do. Do. Do. in Oil. S.	,, × ,,	·380	1104
1152	,, ,, Soft.	,, × ,,	·380	826
1153	Do. Do. Do. Do. in Water. S.	,, × ,,	·380	961
1154	,, ,, Soft.	,, × ,,	·380	1118
1155	MERSEY Co. "Mil-1" Puddled Steel, heated and cooled in Oil. S.	·250 × 2·00	·500	1762
1156	,, ,, ,, Soft.	·250 × 2·00	·500	1228
1157	SHORTRIDGE & Co. "Homo." Steel, heated and cooled in Oil.	·190 × 2·00	·380	1533
1158	,, ,, Soft.	,, × 1·99	·378	990
1159	Do. Do. Do. Do. in Oil.	,, × 2·00	·380	1333
1160	,, ,, Soft.	,, × 2·00	·380	876
1161	Do. Do. Do. Do. in Oil.	,, × 2·00	·380	1319
1162	,, ,, Soft.	,, × 2·00	·380	819
1163	Do. Do. Do. Do. in Oil.	,, × 2·00	·380	1304
1164	,, ,, Soft.	,, × 1·87	·355	762
	RIVETTED STEEL PLATES.			
1165	SHORTRIDGE & Co. "Homo." Steel, Whole Plate.	·190 × 3·00	·570	1647
1166	,, ,, Cut out lengthways from one Plate. Soft— Cut & joined with 2 Rivets	·43	·290 Area of Rivets	333
1167	,, ,, ,, ,, 2 ,,	·43	·290	333
1168	,, ,, ,, ,, 2 ,,	·43	·290	333
1169	,, ,, ,, ,, 2 ,,	·51	·408	562
1170	,, ,, ,, ,, 2 ,,	·56	·492	747
1171	,, ,, ,, ,, 2 ,,	·56	·492	790
1172	,, ,, ,, ,, 3 ,,	·51	·612	848
1173	Do. Do. Hd. in Oil— Do. Do. 2 ,,	·43	·290	333
1174	,, ,, ,, ,, 2 ,,	·43	·290	362
1175	,, ,, ,, ,, 2 ,,	·56	·492	761
1176	,, ,, ,, ,, 2 ,,	·56	·492	790
1177	,, ,, ,, ,, 2 ,,	·60	·565	992
1178	,, ,, ,, ,, 2 ,,	·68	·726	1333

Plates III., IV.

those marked *S.*, which were received from the Makers.

URED. Area.	Difference between *Original & Fractured* Areas.		ELONGATION. Original length of stretched part in column 10.			FRACTURE. Crystalline.	FRACTURE. Kind.
6. sq. in.	7. sq. in.	8. ₱ cent.	9. inch.	10. inches.	11. ₱ cent.	12. ₱ cent.	13.
·356	·016	4·3	·16	5·6	2·9	2	W
			·15	"	2·7	25	T W
·368	·012	3·2	·10	"	1·8	4	W
			·11	"	2·0	15	W
·438	·032	7·0	·17	"	3·0	1*i*	W
			·20	"	3·6	8*i*	W
·470	·006	1·3	·04	"	0·7	25	T W
			·04	"	0·7	80	T
·703	·047	6·3	·21	"	3·7	32*i*	T W
			·25	"	4·5	38	T W
·740	·010	1·3	·06	"	1·1	90	T
			·04	"	0·7	30*i*	T W
·366	·006	1·6	·06	"	1·1	34	T W
			·04	"	0·7	45*i*	T W
·464	·012	2·5	·01	7·6	0·1	54	R
·394	·062	13·6	·61	"	8·0	0	U
·591	·099	14·3	·34	"	4·4	0	U
·476	·000	0·0	·00	"	0·0	80	R
·427	·033	7·2	·46	"	6·0	1	U
·637	·053	7·7	·20	"	2·6	1	U
						Granular.	
·376	·004	1·1	·05	5·6	0·9	86	A I
·372	·008	2·1	·15	"	2·7	78	A I
·376	·004	1·1	·08	"	1·4	85	A I
·363	·017	4·5	·28	"	5·0	38	I
·374	·006	1·6	·09	"	1·6	48	I
·355	·025	6·6	·14	"	2·5	5	J
·378	·002	0·5	·03	"	0·5	68	A I
·366	·014	3·7	·22	"	4·0	82	A I
·345	·035	9·2	·27	"	4·9	00	J
·376	·004	1·1	·12	"	2·1	85	A I
·351	·029	7·6	·23	"	4·2	38	A I
·353	·027	7·1	·18	"	3·2	28	I
·380	·000	0·0	·00	"	0·0	98	A I
·355	·025	6·6	·26	"	4·7	85	A I
·400	·100	20·0	·48	"	8·6	00	J
·437	·063	12·6	·36	"	6·4	33	I
·374	·006	1·6	·08	"	1·4	100	A
·347	·031	8·2	·33	"	5·9	100	A
·323	·077	20·3	·38	"	6·8	95	A D
·279	·101	26·6	·68	"	12·1	00	F
·343	·037	9·7	·31	"	5·7	98	A D
·302	·078	20·5	·60	"	10·7	00	F
·330	·050	13·2	·54	"	9·6	95	A D
·244	·111	31·3	·99	"	17·7	00	G

Rivets.
Shearing Strain, 63,796 lbs. per square inch.
Tensile Strain, 56,450 lbs. per square inch.
Difference, 22,654 lbs. per sq. in., or 26·2 ₱ cent.

30	Rivet heads drawn off.
30	Rivets shearred or cut through centre.
30	Do. do. do.
-	Do. whole, 1 corner of both plates broken off.
-	Do. " 1 plate broken through centre of holes.
-	Do. " 1 " do. do.
-	Do. " 1 " do. do.
30	Rivets sheared or cut through centre.
77	Do. do. do.
14	Do. do. do.
74	Do. do. do.
14	Do. do. do.
04	1 Rivet cut through, and 1 corner of 1 plate broken off.

Representati

NOTE.—All the pieces were taken *promiscuously* from Engineers' or

Index No.	Names of the Makers or Works.	ORIGINAL.		Weight on Steelyard	BREAKING
		Diam.	Area.		Total.
		1. inch.	2. sq. in.	3. lbs.	4. lbs.
1201	GOVAN Hammered-bar. S. A.	0·70	·3848	1033	37,994
1202	" " " B.	0·70	·3848	662	27,606
1203	" " " C.	1·00	·7854	1690	56,390
1204	LOWMOOR (hardest bar.) A.	0·73	·4184	1047	38,386
1205	" " B.	0·73	·4184	733	29,594
1206	" " C.	1·00	·7854	1504	51,182
1207	BOWLING (softest bar.) A.	0·73	·4184	676	27,998
1208	" " B.	0·72	·4071	491	22,818
1209	" " C.	1·00	·7854	1322	46,086
1210	BRADLEY'S B. B. Scrap. S. A.	0·70	·3848	758	30,294
1211	" " " B.	0·70	·3848	538	23,994
1212	" " " C.	1·00	·7854	1347	46,786
1213	Do. Do. S. A.	0·70	·3848	783	29,594
1214	" " " B.	0·71	·3958	558	24,694
1215	" " " C.	1·00	·7854	1359	47,122
1216	◈ GOVAN ◈ A.	0·70	·3848	640	26,690
1217	" " B.	0·69	·3739	442	21,446
1218	" " C.	1·01	·8012	1318	45,974
1219	Do. Do. A.	0·71	·3958	676	27,998
1220	" " B.	0·70	·3848	533	23,994
1221	" " C.	1·02	·8171	1361	47,178
1222	GLASGOW B. Best (softest bar.) A.	0·70	·3848	562	24,806
1223	" " " B.	0·70	·3848	505	23,210
1224	" " " C.	0·98	·7543	1248	44,014
1225	Do. Do. do. A.	0·70	·3848	562	24,806
1226	" " " B.	0·71	·3958	533	23,994
1227	" " " C.	0·98	·7543	1248	44,014
1228	Do. Do. A.	0·70	·3848	761	30,378
1229	" " B.	0·70	·3848	640	26,690
1230	" " C.	1·00	·7854	1347	46,786
1231	Do. Do. (hardest bar.) A.	0·71	·3958	790	31,190
1232	" " " B.	0·70	·3848	562	24,806
1233	" " " C.	1·00	·7854	1382	47,766
1234	BLOCHAIRN B. Best. A.	0·73	·4184	704	28,782
1235	" " B.	0·73	·4184	597	25,786
1236	" " C.	1·00	·7854	1304	45,582
1237	PORT-DUNDAS Ex. B. Best. A.	0·71	·3958	533	23,994
1238	" " B.	0·70	·3848	351	18,898
1239	" " C.	1·09	·9332	1162	41,606
1240	DUNDYVAN (common.) A.	0·73	·4184	676	27,998
1241	" " B.	0·73	·4184	619	26,402
1242	" " C.	1·02	·8171	1190	42,390
1243	LOWMOOR. A.	0·77	·4657	890	33,990
1244	" C.	1·00	·7854	1433	49,194

Fractures, &c., in Plate XV.

Stores, except those marked *S.*, which were received from the Makers.

ORDER OF SUCCESSION.			FRACTURED.				ORDER OF SUCCESSION.			FRACTURE.	
			Diameter	Area.	Difference.					Crystalline.	Kind.
6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
A.	*B.*	*C.*	inch.	sq. in.	sq. in.	℔ cent.	*A.*	*B.*	*C.*	℔ cent.	
1			·65	·3318	·0530	13·77	6			0r	K
	1		·56	·2462	·1386	36·02		10		0r	J
		1	·77	·4657	·3197	40·71			9	0	J
2			·70	·3848	·0336	8·03	11			98	M
	2		·52	·2124	·2060	49·23		5		0	L
		2	·70	·3848	·4006	51·00			4	0	L
10			·62	·3019	·1165	27·84	1			0	B
	12		·48	·1809	·2262	55·56		1		0	A
		7	·66	·3421	·4433	56·44			1	0	A
5			·63	·3116	·0732	19·02	4			0rr	F
	7		·49	·1885	·1963	51·01		3		0r	E
		5	·69	·3739	·4115	52·41			2	0r	E
6			·63	·3116	·0732	19·02	5			0rr	F
	6		·50	·1963	·1996	50·40		4		0r	E
		4	·70	·3848	·4006	51·01			3	0r	E
8			·61	·2922	·0926	24·06	2			0r	D
	13		·47	·1735	·2004	53·60		2		0	C
		12	·72	·4071	·3041	49·19			5	0	C
7			·63	·3116	·0842	21·27	3			2	D
	8		·51	·2043	·1805	46·91		6		0	C
		11	·74	·4300	·3871	47·38			6	0	C
12			·65	·3318	·0630	13·77	7			4r	H
	11		·54	·2290	·1558	40·49		7		0	G
		8	·75	·4417	·3126	41·44			7	1	G
13			·65	·3318	·0530	13·77	8			0r	H
	10		·55	·2376	·1582	39·97		8		0	G
		9	·75	·4417	·3126	41·44			8	1	G
3			·66	·3421	·0427	11·09	9			84	Q
	3		·57	·2552	·1296	33·70		11		0	P
		6	·78	·4779	·3075	39·15			10	1	P
4			·69	·3739	·0219	5·54	13			96	S
	4		·64	·3216	·0632	16·42		12		88	R
		3	·82	·5281	·2573	32·76			11	25	R P
9			·70	·3848	·0336	8·03	12			70	O
	9		·58	·2642	·1542	36·85		9		0	N
		10	·85	·5674	·2180	27·76			12	12	N P
14			0·68	·3632	·0326	8·24	10			55	U
	14		0·66	·3421	·0427	11·09		13		78	T
		14	1·03	·8332	·0999	10·71			13	48	T
11			0·73	·4184	·0000	0·00	14			100	W
	5		0·70	·3848	·0336	8·03		14		98	V
		13	1·00	·7854	·0317	3·88			14	100	V
			0·71	·3968	·0699	15·01				90	M
			0·68	·3632	·4222	53·76				0	L

Representations

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Merc

Index No.	Names of the Makers or Works, and how Treated.		Diameter.	Weight on Steel-yard.	BREAKING STRAIN, Total on Specimen.		BREAKING STR Screwed.	
			1. in.	3. lbs.	4. lbs.	5. lbs.	6. lbs.	7. lbs.
1301	◈ GOVAN ◈	Screwed.	1¼	1704	56,782	56,237	46,273	45,911
1302	,, ,,	,,	,,	1704	56,782		46,273	
1303	,, ,,	,,	,,	1704	56,782		46,273	
1304	,, ,,	,,	,,	1690	56,390		45,954	
1305	,, ,,	,,	,,	1690	56,390		45,954	
1306	,, ,,	,,	,,	1675	55,970		45,611	
1307	,, ,,	,,	,,	1690	56,390		45,954	
1308	,, ,,	,,	,,	1648	55,214		44,966	
1309	GLASGOW B. Best.	Screwed.	1¼	1717	57,146	50,510	46,570	41,161
1310	,, ,,	,,	,,	1717	57,146		46,570	
1311	,, ,,	,,	,,	1648	55,214		44,996	
1312	,, ,,	,,	,,	1593	53,674		43,730	
1313	,, ,,	,,	,,	1561	52,778		43,010	
1314	,, ,,	,,	,,	1504	51,182		41,709	
1315	,, ,,	,,	,,	1447	49,586		40,410	
1316	,, ,,	,,	,,	1418	48,774		39,747	
1317	,, ,,	,,	,,	1390	47,990		39,108	
1318	,, ,,	,,	,,	1297	45,386		36,986	
1319	,, ,,	,,	,,	1248	44,014		35,870	
1320	,, ,,	,,	,,	1220	43,230		35,230	
1321	Do. Do.	Chased.	1¼	1560	52,750	48,569	42,988	39,548
1322	,, ,,	,,	,,	1462	50,006		40,751	
1323	,, ,,	,,	,,	1447	49,586		40,409	
1324	,, ,,	,,	,,	1361	47,178		38,447	
1325	,, ,,	,,	,,	1447	49,586		40,409	
1326	,, ,,	,,	,,	1346	46,758		38,104	
1327	,, ,,	,,	,,	1332	46,366		37,785	
1328	,, ,,	,,	,,	1319	46,002		37,488	
1329	BAGNALL ⚜ J B	Chased.	1¼	1361	47,178	45,533	38,447	37,106
1330	,, ,,	,,	,,	1354	46,982		38,287	
1331	,, ,,	,,	,,	1247	43,986		35,845	
1332	,, ,,	,,	,,	1247	43,986		35,845	
1333	Do. Do.	Screwed.	1¼	1504	51,182	49,647	41,709	40,459
1334	,, ,,	,,	,,	1418	48,774		39,748	
1335	,, ,,	,,	,,	1497	50,986		41,550	
1336	,, ,,	,,	,,	1418	48,774		39,748	
1337	,, ,,	,,	,,	1440	49,390		40,249	
1338	,, ,,	,,	,,	1418	48,774		39,748	
1339	DUNDYVAN (common.)	Screwed.	1¼	1535	52,050	48,225	42,417	39,300
1340	,, ,,	,,	,,	1504	51,182		41,709	
1341	,, ,,	,,	,,	1492	50,846		41,436	
1342	,, ,,	,,	,,	1418	48,774		39,747	
1343	,, ,,	,,	,,	1390	47,990		39,108	
1344	,, ,,	,,	,,	1361	47,178		38,447	
1345	,, ,,	,,	,,	1376	47,598		38,789	
1346	,, ,,	,,	,,	1361	47,178		38,447	
1347	,, ,,	,,	,,	1347	46,786		38,127	
1348	,, ,,	,,	,,	1361	47,178		38,447	
1349	,, ,,	,,	,,	1332	46,366		37,785	
1350	,, ,,	,,	,,	1304	45,582		37,146	
1351	BLOCHAIRN B. Best.	Screwed.	1	819	32,202	29,965	40,743	38,116
1352	,, ,,	,,	,,	791	31,190		39,712	
1353	,, ,,	,,	,,	791	31,190		39,712	
1354	,, ,,	,,	,,	733	29,594		37,680	
1355	,, ,,	,,	,,	733	29,594		37,680	
1356	,, ,,	,,	,,	676	27,998		35,645	
1357	,, ,,	,,	,,	676	27,998		35,648	
1358	DUNDYVAN (common.)	Screwed.	1	720	29,230	26,994	37,217	34,344
1359	,, ,,	,,	,,	647	27,186		34,614	
1360	,, ,,	,,	,,	561	24,778		31,548	
1361	,, ,,	,,	,,	676	27,998		35,648	
1362	,, ,,	,,	,,	662	27,606		55,149	
1363	,, ,,	,,	,,	620	26,430		33,651	
1364	,, ,,	,,	,,	590	25,590		32,589	

res, &c., in Plate XVI.

, except those marked *S.*, which were received from the Makers.

ER SQUARE INCH. Unscrewed.		Difference between Screwed and Unscrewed Bars.				EQUIVALENT.		FRACTURE.	
						Reduction in Diameter by Screwing.	Diam. of an Unscrewed Bar.	Crys.	Kind.
9. lbs.	10. lbs.	11. lbs.	12. lbs.	13. ₩ cent.	14. ₩ cent.	15. inches.	16. inches.	17. ₩ cent.	18.
56,067	57,598	9,794	11,687	17·47	20·24	·135	1·115	1*r*	B C
„		9,794		17·47				4*r*	B C
58,321		12,048		20·66				27*r*	B C
„		12,367		21·20				15*r*	B E
56,701		10,747		18·95				98	B C
„		11,090		19·56				62*rr*	B E
59,302		13,348		22·51				98	B E
„		14,306		24·12				62*r*	B E
56,404	54,579	9,834	13,416	17·43	24·69	·165	1·085	68	C E
„		9,834		17·43				72	C E
„		11,408		20·22				55*r*	C E
55,697		11,967		21·50				30	C E
„		12,687		22·77				36*r*	C E
„		13,888		24·92				13*r*	C E
53,439		13,029		24·38				22*r*	C E
„		13,692		25·62				25*r*	C E
„		14,331		26·82				50*r*	C E
52,776		15,790		29·92				86	C E
„		16,906		32·03				30*r*	C E
„		17,546		33·24				45*r*	C E
56,404	54,579	13,416	15,031	23·78	27·55	·186	1·084	92	E
„		15,653		27·75				75*r*	C E
55,697		15,288		27·45				10*r*	C
„		17,250		30·97				8*r*	C
53,439		13,030		24·38				22*r*	C E
„		15,335		28·70				8*r*	C
52,776		14,991		28·45				15*r*	C E
„		15,288		28·97				38*r*	C E
54,123	55,000	15,676	17,894	28·97	32·50	·223	1·027	7	C
54,731		16,444		30·04				2	C
55,081		19,236		34·92				22*r*	C E
56,067		20,222		36·06				38	C E
56,067	55,000	14,358	14,631	25·61	26·54	·178	1·072	92	E
„		16,319		29·01				35*r*	C E
54,123		12,573		23·23				22	C E
„		14,375		26·56				10*r*	C E
55,081		14,832		26·92				98	E
„		15,333		27·84				46	C E
58,640	51,327	16,223	12,027	27·67	23·40	·156	1·094	95	F
„		16,931		28·89				98	F
„		17,204		29·34				98	F
51,521		11,774		22·85				98	F
„		12,413		24·09				97	F
„		13,074		25·38				99	F
49,536		10,747		21·70				99	F
„		11,069		22·39				98	F
„		11,409		23·03				95*r*	F
45,611		7,164		15·71				99	F
„		7,826		17·16				99	F
„		8,465		18·56				85	F
58,049	55,730	17,306	17,602	29·81	31·61	·178	·887	54*r*	C E
„		18,337		31·59				96	E
„		18,337		31·59				48*r*	C E
53,972		16,292		30·19				1*r*	C
„		16,292		30·19				1*r*	C
„		18,324		33·95				2*r*	C
„		18,324		33·95				1*r*	C
51,879	50,214	14,662	15,870	28·26	31·55	·178	·887	100	F
„		17,265		33·28				98	F
„		20,331		39·19				95	F
48,966		13,318		27·20				92	F
„		13,817		28·22				75	F
„		15,315		31·27				95*r*	F
„		16,384		33·46				88*r*	F

Representations

Note.—All the pieces were taken *promiscuously* from Engineers' or Merch

Index No.	Names of the Makers or Works, and how Treated.			Diameter.	Weight on Steel-yard.	BREAKING STRAIN, Total on Specimen.		BREAKING STR Screwed	
				1. in.	3. lbs.	4. lbs.	5. lbs.	6. lbs.	7. lbs.
1365	Lowmoor.		Screwed.	1	1355	47,010	43,321	59,855	55,158
1366	,,		old dies.	,,	1276	44,798		57,039	
1367	,,		,,	,,	1248	44,014		56,040	
1368	,,		,,	,,	1218	43,174		54,970	
1369	,,		,,	,,	1218	43,174		54,970	
1370	,,		,,	,,	1205	42,810		54,508	
1371	,,		,,	,,	1133	40,794		51,940	
1372	,,		,,	,,	1133	40,794		51,940	
1373	Do.		Do.	1	933	35,194	33,496	44,810	42,647
1374	,,		new dies.	,,	933	35,194		44,810	
1375	,,		,,	,,	933	35,194		44,810	
1376	,,		,,	,,	904	34,382		43,776	
1377	,,		,,	,,	819	32,002		40,743	
1378	,,		,,	,,	819	32,002		40,743	
1379	,,		,,	,,	819	32,002		40,743	
1380	,,		,,	,,	819	32,002		40,743	
1381	Do.		Chased.	1	997	36,986	35,231	47,092	44,858
1382	,,		,,	,,	933	35,194		44,810	
1383	,,		,,	,,	933	35,194		44,810	
1384	,,		,,	,,	933	35,194		44,810	
1385	,,		,,	,,	905	34,410		43,812	
1386	,,		,,	,,	905	34,410		43,812	
1387	Bowling.		Screwed.	1	976	36,398	35,595	46,343	45,321
1388	,,		new dies.	,,	933	35,194		44,810	
1389	,,		,,	,,	933	35,194		44,810	
1390	Bradley Ⓛ	S.	Screwed.	1	996	36,958	36,626	47,039	46,633
1391	,, ,,	,,	old dies.	,,	961	35,978		45,809	
1392	,, ,,	,,	,,	,,	990	36,790		46,842	
1393	,, ,,	,,	,,	,,	990	36,790		46,842	
1394	Bradley B. B. Scrap.	S.	Do.	1	920	34,830	34,221	44,347	43,571
1395	,, ,,	,,	new dies.	,,	905	34,410		43,812	
1396	,, ,,	,,	,,	,,	920	34,830		44,347	
1397	,, ,,	,,	,,	,,	848	32,814		41,780	
1398	◈ Govan ◈		Screwed.	1	961	35,978	34,590	45,809	44,035
1399	,, ,,		new dies.	,,	876	33,598		42,778	
1400	,, ,,		,,	,,	904	34,392		43,776	
1401	,, ,,		,,	,,	904	34,392		43,776	
1402	Do. Do.		Chased.	1	933	35,194	33,703	44,810	42,912
1403	,, ,,		,,	,,	876	33,598		42,778	
1404	,, ,,		,,	,,	862	33,206		42,280	
1405	,, ,,		,,	,,	848	32,814		41,780	
1406	Glasgow B. Best.	1	Screwed.	1	1075	39,170	35,574	49,873	45,294
1407	,, ,,	2	old dies.	,,	1047	38,386		48,874	
1408	,, ,,	3	,,	,,	1004	37,182		47,341	
1409	,, ,,	2	,,	,,	990	36,790		46,842	
1410	,, ,,	3	,,	,,	933	35,194		44,810	
1411	,, ,,	1	,,	,,	876	33,598		42,778	
1412	,, ,,	3	,,	,,	1004	37,182		47,341	
1413	,, ,,	1	,,	,,	876	33,598		42,778	
1414	,, ,,	2	,,	,,	876	33,598		42,778	
1415	,, ,,	1	,,	,,	961	35,978		45,809	
1416	,, ,,	2	,,	,,	961	35,978		45,809	
1417	,, ,,	3	,,	,,	848	32,184		40,978	
1418	,, ,,	3	,,	,,	961	35,978		45,809	
1419	,, ,,	2	,,	,,	933	35,194		44,810	
1420	,, ,,	1	,,	,,	876	33,598		42,778	
1421	Do. Do.		Screwed.	1	804	31,582	30,518	40,211	38,856
1422	,, ,,		new dies.	,,	804	31,582		40,211	
1423	,, ,,		,,	,,	761	30,378		38,678	
1424	,, ,,		,,	,,	761	30,378		38,678	
1425	,, ,,		,,	,,	733	29,594		37,680	
1426	,, ,,		,,	,,	733	29,594		37,680	

OLTS. TABLE Q, DETAIL.

actures, &c., in Plate XVI.

res, except those marked S., which were received from the Makers.

	PER SQUARE INCH.		Difference between Screwed and Unscrewed Bars.				EQUIVALENT.		FRACTURE.	
	Unscrewed.						Reduction in Diameter by Screwing.	Diam. of an Unscrewed Bar.	Crys.	Kind.
8,	9.	10.	11.	12.	13.	14.	15.	16,	17.	18.
o.	lbs.	lbs.	lbs.	lbs.	⅌ cent.	⅌ cent.	inches.	inches.	⅌ cent.	
406	65,166	61,896	5,311	6,735	8·15	10·91	·056	·944	100	D
.406	62,635		5,596		8·93				100	D
,,	,,		6,595		10·53				100	D
,,	,,		7,665		12·24				100	D
,,	,,		7,665		12·24				100	D
408	59,320		4,812		8·11				100	D
407	60,069		8,129		13·53				1	B
,,	,,		8,129		13·53				1	B
.407	60,069	60,710	15,259	18,063	25·40	29·70	·161	·839	30r	B D
,,	,,		15,259		25·40				10r	B D
,,	,,		15,259		25·40				12r	B D
,,	,,		16,293		27·12				20r	B D
,,	,,		19,326		32·17				r12r	B D
,,	,,		19,326		32·17				15r	B D
106	62,635		21,892		34·95				20r	B D
,,	,,		21,892		34·95				0	B
105	65,166	62,623	18,074	17,765	27·74	28·34	·153	·847	5r	B
,,	,,		20,356		31·24				0r	B
106	62,635		17,825		28·46				5r	B
,,	,,		17,825		28·46				30r	B D
107	60,069		16,257		27·06				2	B
,,	,,		16,257		27·06				15r	B D
124	58,678	58,678	12,335	13,357	21·02	22·76	·121	·879	0r	B
,,	,,		13,868		23·63				0r	B
,,	,,		13,868		23·63				0r	B
125	57,039	57,537	10,000	10,904	17·53	18·95	·100	·900	r1r	A
,,	,,		11,230		19·69				r1r	A
133	58,036		11,194		19·29				r8r	A
,,	,,		11,194		19·29				r5r	A
128	59,570	59,784	15,223	16,213	25·55	27·11	·146	·854	r1r	A
,,	,,		15,758		26·45				r22r	A D
137	59,988		15,651		26·09				r1r	A
,,	,,		18,218		30·36				r1r	A
724	57,738	58,732	11,929	14,697	20·66	25·01	·134	·866	2r	B C
,,	,,		14,960		25·94				18r	B D
721	59,726		15,950		26·72				0r	B C
,,	,,		15,950		26·72				0r	B C
723	58,252	58,761	13,442	15,849	23·08	26·98	·146	·854	2r	B C
,,	,,		15,474		26·56				3r	B C
722	59,270		16,990		28·66				r5r	B C
,,	,,		17,490		29·51				14r	B D
214	59,569	58,885	9,696	13,591	16·28	23·07	·123	·877	90	E
,,	,,		10,695		17·96				25r	C E
,,	,,		12,228		20·53				25r	C E
213	60,817		13,975		22·98				100	E
,,	,,		16,007		26·32				100	E
,,	,,		18,039		29·66				100	E
215	59,369		12,228		20·53				45	C E
,,	,,		16,791		28·18				95	E
,,	,,		16,791		28·18				90	E
17	56,121		10,312		18·37				80	E C
,,	,,		10,312		18·37				12r	C E
,,	,,		15,143		26·96				1r	C
16	58,351		12,542		21·49				95	E
,,	,,		13,541		23·20				98	E
,,	,,		15,573		26·69				90	E
16	58,351	58,351	18,140	19,496	31·09	33·41	·174	·826	8r	C
,,	,,		18,140		31·09				3r	C
,,	,,		19,673		33·71				15r	C E
,,	,,		19,673		33·71				1r.	C
,,	,,		20,671		35·42				18r	C E
,,	,,		20,671		35·42				20	C E

Representations (

NOTE.—All the pieces were taken *promiscuously* from Engineers' or Merc

Index No.	Names of the Makers or Works, and how Treated.		Diameter.	Weight on Steel-yard.	BREAKING STRAIN. Total on Specimen.		BREAKING STR Screwed.	
			1. in.	3. lbs.	4. lbs.	5. lbs.	6. lbs.	7. lbs.
1427	◈ GOVAN ◈	Screwed, old dies.	¾	274	16,742		54,570	
1428	" "		"	274	16,742		54,570	
1429	" "	"	"	253	16,154		52,653	
1430	" "	"	"	281	16,938		55,208	
1431	" "	"	"	278	16,854		54,935	
1432	" "	"	"	253	16,154		52,653	
1433	" "	"	"	274	16,742	16,523	54,570	[illegible]
1434	" "	"	"	274	16,742		54,570	
1435	" "	"	"	253	16,154		52,653	
1436	" "	"	"	281	16,938		55,208	
1437	" "	"	"	260	16,350		53,292	
1438	" "	"	"	239	15,762		51,375	
1439	Do. Do.	Do. new dies.	¾	218	15,174		49,460	
1440	" "		"	211	14,978		48,820	
1441	" "	"	"	208	14,894		48,546	
1442	" "	"	"	211	14,978		48,820	
1443	" "	"	"	211	14,978		48,820	
1444	" "	"	"	204	14,782		48,181	
1445	" "	"	"	222	15,286	14,680	49,824	[illegible]
1446	" "	"	"	201	14,698		47,907	
1447	" "	"	"	190	14,390		46,903	
1448	" "	"	"	190	14,390		46,903	
1449	" "	"	"	176	13,998		45,626	
1450	" "	"	"	162	13,606		44,348	
1451	GLASGOW B. Best.	Screwed, old dies.	¾	268	16,574		54,022	
1452	" "		"	260	16,350		53,292	
1453	" "	"	"	232	15,566		50,737	
1454	" "	"	"	281	16,938		55,208	
1455	" "	"	"	253	16,154		52,653	
1456	" "	"	"	225	15,370		50,098	
1457	" "	"	"	243	15,874	14,222	51,740	[illegible]
1458	" "	"	"	215	15,090		49,185	
1459	" "	"	"	204	14,782		48,181	
1460	" "	"	"	225	15,370		50,098	
1461	" "	"	"	222	15,286		49,824	
1462	" "	"	"	204	14,782		48,181	
1463	Do. Do.	Do. new dies.	¾	190	14,390		46,903	
1464	" "		"	184	14,222		46,390	
1465	" "	"	"	159	13,552		44,074	
1466	" "	"	"	187	14,306		46,630	
1467	" "	"	"	176	13,998		45,626	
1468	" "	"	"	148	13,214		43,070	
1469	" "	"	"	159	13,552	13,378	44,074	[illegible]
1470	" "	"	"	148	13,214		43,070	
1471	" "	"	"	148	13,214		43,070	
1472	" "	"	"	115	12,290		40,059	
1473	" "	"	"	115	12,290		40,059	
1474	" "	"	"	115	12,290		40,059	
1475	Do. Do.	Chased.	¾	159	13,552		44,074	
1476	" "	"	"	148	13,214		43,070	
1477	" "	"	"	148	13,214	12,785	43,070	[illegible]
1478	" "	"	"	127	12,626		41,154	
1479	" "	"	"	113	12,234		39,876	
1480	" "	"	"	100	11,870		38,690	

OLTS. TABLE Q, DETAIL.

ctures, &c., in Plate XVI.

res, except those marked S, which were received from the Makers.

PER SQUARE INCH, Unscrewed.			Difference between Screwed and Unscrewed Bars.				EQUIVALENT.		FRACTURE.	
							Reduction in Diameter by Screwing.	Diam. of an Unscrewed Bar.	Crys.	Kind.
	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
	lbs.	lbs.	lbs.	lbs.	⅌ cent.	⅌ cent.	inches.	inches.	⅌ cent.	
28	55,526	58,199	0,956	4,344	1·72	7·46	·024	·601	0	H
"	"		0,956		1·72				0r	H
"	"		2,873		5·17				0	H
27	56,784		1,576		2·78				0	H
"	"		1,849		3·25				0r	H
"	"		4,131		7·29				0	H
25	60,558		5,988		9·69				0	H
"	"		5,988		9·89				0r	H
"	"		7,905		13·05				0	H
26	59,929		4,721		7·88				0r	H
"	"		6,637		11·07				0	H
"	"		8,554		14·27				0r	H
28	55,526	58,199	6,066	10,353	10·92	17·78	·058	·567	0	H
"	"		6,706		12·08				0	H
"	"		7,980		14·37				0	H
27	56,784		7,964		14·02				0	H
"	"		7,964		14·02				0	H
"	"		8,603		15·15				0	H
25	60,558		10,734		17·78				0	H
"	"		12,651		20·89				0	H
"	"		13,655		22·55				0	H
26	59,929		13,026		21·74				0	H
"	"		14,303		23·87				0r	H
"	"		15,581		26·00				0r	H
742	59,929	59,300	5,907	8,199	9·86	13·82	·045	·580	3	H G
"	"		6,637		11·07				72	G
"	"		9,192		15·34				50	G
744	58,671		3,463		5·90				0	H
"	"		6,018		10·26				0	H
"	"		8,573		14·61				0	H
743	58,671		6,931		11·81				0r	H
"	"		9,486		16·17				0r	H
"	"		10,490		17·90				0r	H
741	59,929		9,831		16·40				9r	H G
"	"		10,105		16·86				6r	H G
"	"		11,748		19·60				4r	H G
42	59,929	59,300	13,026	15,700	21·74	26·47	·089	·536	25	H G
"	"		13,539		22·59				4	H G
"	"		15,855		26·46				6	H G
43	58,671		12,041		20·52				0	H
"	"		13,045		22·23				0	H
"	"		15,601		26·59				0	H
44	58,671		14,597		24·88				0	H
"	"		15,601		26·59				0	H
"	"		15,601		26·59				0	H
41	59,929		19,870		33·16				6	H G
"	"		19,870		33·15				6	H G
"	"		19,870		33·16				9	H G
42	59,929	59,300	15,855	17,644	26·46	29·75	·101	·524	6	H G
43	58,671		15,601		26·59				0r	H
42	59,929		16,859		28·13				4	H G
44	58,671		17,517		29·86				0	H
44	58,671		18,795		32·03				0	H
41	59,929		21,239		35·44				0	H

SCREWED AND CHASED

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchant

Reference No.	No. of Experiments on each.	Names of the Makers or Works, and how Treated.		Diameter.	Index Nos. Table Q.	BREAKING STRAIN, PER SCREWED, Highest.	Lowest.	Mean.
						1. lbs.	2. lbs.	3. lbs.
		IRON BARS.						
601	8	◇ Govan ◇	Screwed.	1¼	1301-1308	46,273	44,966	[illegible]
602	12	Glasgow B. Best.	"	"	1309-1320	46,570	35,230	[illegible]
603	6	Bagnall ₩ J B.	"	"	1333-1338	41,709	39,748	[illegible]
604	12	Dundyvan.	"	"	1339-1350	42,417	37,146	[illegible]
605	8	Glasgow B. Best.	Chased.	1¼	1321-1328	42,988	37,488	[illegible]
606	4	Bagnall ₩ J B.	"	"	1329-1332	38,447	35,845	[illegible]
607	8	Lowmoor.	Screwed, old dies.	1	1365-1372	59,855	51,940	[illegible]
608	4	Bradley Ⓛ *S.*		"	1390-1393	47,039	45,809	[illegible]
609	15	Glasgow B. Best.	"	"	1406-1420	49,873	40,978	[illegible]
610	8	Lowmoor.	Screwed, new dies.	1	1373-1380	44,810	40,763	[illegible]
611	3	Bowling.		"	1387-1389	46,343	44,810	[illegible]
612	4	Bradley B. B. Scrap. *S.*	"	"	1394-1397	44,347	41,780	[illegible]
613	4	◇ Govan ◇	"	"	1398-1401	45,809	42,778	[illegible]
614	6	Glasgow B. Best.	"	"	1421-1426	40,211	37,680	[illegible]
615	7	Blochairn B. Best.	"	"	1351-1357	40,743	35,648	[illegible]
616	7	Dundyvan.	"	"	1358-1364	37,217	31,548	[illegible]
617	4	◇ Govan ◇	Chased.	1	1402-1405	44,810	41,780	[illegible]
618	6	Lowmoor.	"	"	1381-1386	47,092	43,812	[illegible]
619	12	◇ Govan ◇	Screwed, old dies.	⅞	1427-1438	55,208	51,375	[illegible]
620	12	Glasgow B. Best.		"	1451-1462	55,208	48,181	[illegible]
621	12	◇ Govan ◇	Screwed, new dies.	⅞	1439-1450	49,824	44,348	[illegible]
622	12	Glasgow B. Best.		"	1463-1474	46,903	40,059	[illegible]
623	6	Glasgow B. Best.	Chased.	⅞	1475-1480	44,074	38,690	[illegible]
	180							

WELDED JOINTS.

Note.—All the pieces were taken *promiscuously* from Engineers' or Merchant

Index No.	Names of the Makers or Works, and how Treated.	ORIGINAL Diam.	ORIGINAL Area.	Weight on Steel-yard.	BREAKING STRAIN, Total on Specimen.		BREAKING STR WELDED.	
		1. inch.	2. sq. in.	3. lbs.	4. lbs.	5. lbs.	6. lbs.	7. lbs.
	IRON BARS.							
1481	Glasgow B. Best. Welded by smith.	1·25	1·2271	2018	65,574	55,592	53,439	[illegible]
1482	" " " "	"	"	1935	63,250		51,544	
1483	" " " "	"	"	1733	57,594		46,935	
1484	" " " "	"	"	1675	55,970		45,611	
1485	" " " "	"	"	1561	52,778		43,010	
1486	" " " "	"	"	1047	38,386		31,288	
1487	Farnley. Do. Do.	1·00	·7854	1104	39,982	34,788	50,908	[illegible]
1488	" " " "	"	"	990	36,790		46,842	
1489	" " " "	"	"	819	32,002		40,746	
1490	" " " "	"	"	761	30,378		38,678	
1491	Govan B. Best. Do. Do.	·76	·4536	590	25,590	22,797	56,415	[illegible]
1492	" " " "	·76	·4536	569	25,002		55,119	
1493	" " " "	·75	·4417	407	20,466		46,335	
1494	" " " "	·76	·4536	421	20,858		45,983	
1495	Govan Ex. B. Best. Do. by chain-maker	·76	·4536	605	26,010	21,411	57,341	48,984
1496	" " " "	·76	·4536	598	25,814		56,909	
1467	" " " "	·76	·4536	420	20,830		45,921	
1498	" " " "	·68	·3632	140	12,990		35,765	
	STEEL BARS.							
1499	Moss & Gamble. Welded by the Makers. *S.*	·75	·4417	619	26,402	23,630	59,773	53,498
1500	" " " " *S.*	·75	·4417	421	20,858		47,222	

TS. TABLE R, SUMMARY.

xcept those marked S., which were received from the Makers.

IN. WED.	DIFFERENCE BETWEEN SCREWED AND UNSCREWED BARS. Least. 5. lbs.	Least. 6. ℘ cent.	Greatest. 7. lbs.	Greatest. 8. ℘ cent.	Mean. 9. lbs.	Mean. 10. ℘ cent.	EQUIVALENT. Reduction in Diameter by Screwing. 11. inches.	EQUIVALENT. Diam. of an Unscrewed Bar. 12. inches.	FRACTURES, Crystalline. 13. ℘ cent.
8	9,794	17·47	14,306	24·12	11,687	20·24	·135	1·115	46
9	9,834	17·43	17,546	33·34	13,416	21·69	·165	1·085	44
0	12,573	23·23	16,319	29·01	14,631	26·54	·178	1·072	51
7	7,164	15·71	17,204	29·34	12,027	23·40	·156	1·094	97
9	13,030	23·78	17,250	30·97	15,031	27·55	·186	1·064	32
0	15,676	28·97	20,222	36·06	17,894	32·50	·223	1·027	17
3	4,812	8·11	8,129	13·53	6,735	10·91	·056	0·944	75
7	10,000	17·53	11,230	19·69	10,904	18·95	·100	0·900	4
5	9,696	16·28	18,039	29·66	13,591	23·07	·123	0·877	70
0	15,259	25·40	21,892	34·95	18,063	29·70	·161	0·839	15
8	12,335	21·02	13,868	23·63	13,257	22·76	·121	0·879	0
4	15,223	25·55	18,218	30·36	16,213	27·11	·146	0·854	6
2	11,929	20·66	15,950	26·72	14,697	25·01	·134	0·866	5
1	18,140	31·09	20,671	35·42	19,495	33·41	·174	0·826	11
0	16,292	29·81	18,387	33·95	17,602	31·61	·173	0·827	29
4	13,318	27·20	20,331	39·19	15,870	31·55	·173	0·827	92
1	13,442	23·08	17,490	29·51	15,849	26·98	·146	0·854	6
3	16,257	27·06	20,356	31·24	17,765	28·34	·153	0·847	9
9	0,956	1·72	8,554	14·27	4,344	7·46	·024	0·601	0
0	3,463	5·90	•11,748	19·60	8,199	13·82	·045	0·580	12
9	6,066	10·92	15,581	26·00	10,353	17·78	·058	0·567	0
0	12,041	20·52	19,870	33·16	15,700	26·47	·089	0·536	5
0	15,601	26·46	21,239	35·44	17,644	29·75	·101	0·524	2

LE S, DETAIL.

xcept those marked S., which were received from the Makers.

QUARE INCH, WELDED. 9. lbs.	10. lbs.	DIFFERENCE BETWEEN WELDED AND UNWELDED BARS. 11. lbs.	12. lbs.	13. ℘ ct.	14. ℘ cent.	EQUIVᵗ. Diameter of a Bar Unwelded. 15. inches.	ELONGATION, Original length of stretched part in Column 18. 16. in.	17. in.	18. in.	19. ℘ c.	FRACTURE, Crys 20. ℘ ct	Where. 21.
55,697	54,952	2,258	9,648	4·1	17·6	1·135	·78	·40	6·0	6·7	48	solid
56,404		4,860		8·6			·58				82	solid
52,776		5,841		11·7			·40				40	solid & weld
53,439		7,828		14·6			·25				18	solid & weld
55,697		12,687		22·8			·27				15	solid & weld
55,697		24,409		43·8			·11				25	solid & weld
64,133	62,868	13,225	18,575	20·6	30·2	0·836	·75	·44	6·0	7 3	0	solid & weld
64,133		17,291		29·3			·42				2	solid & weld
63,634		22,888		35·9			·26				0	weld
59,570		20,892		35·1			·32				0	weld
61,106	59,548	4,691	8,585	7·7	14·5	0·701	·80	·47	8 0	5·9	0	solid
59,316		4,197		7·1			·68				1	solid
58,886		12,551		21·3			·18				18	solid&weld
58,884		12,901		21·9			·20				65	solid&weld
59,070	57,591	1,729	8,607	2·9	15·1	0·683	1·25	·84	8·0	10 5	0	solid
58,452		1,543		2·6			1·56				0	solid
55,653		9,732		17·5			0·46				45	solid & weld
57,190		21,425		37·4			0·08				0	weld
											Gran	
108,649	112,706	48,876	59,208	45·0	52·3	0·518	·06	·04	6·0	0·7	63	solid & weld
116,763		69,541		59·6			·02				38	solid & weld

SUDDENLY AP

Representations of the

NOTE.—All the pieces were taken *promiscuously* from Engineers'

Index No.	Names of the Makers or Works.		ORIGINAL.		Weight on Steel-yard.	SUDDEN APPLIED STRAIN, Per Sq. In.	FRACTURED OR	
			Diam.	Area.			Diam.	Area.
			1.	2.	3.	4.	5.	6.
			inch.	sq. in.	lbs.	lbs.	inch.	sq. in.
1501	**BRADLEY** Ⓛ *S.*		1·00	·7854	1390	60,848	·67f	·3526
1502	" " "		"	"	1390	60,848	·66f	·3421
1503	" " "		"	"	1076	49,909	·63f	·3116
1504	" " "		"	"	1047	48,875	·77s	·4657
1505	**BRADLEY** B. B. Scrap. *S.*		1·00	·7854	1276	57,039	·75f	·4417
1506	" " "		1·00	·7854	1161	52,938	·72f	·4071
1507	**BRADLEY** ⚜ **S C**		0·89	·6220	762	48,874	·87f	·5945
1508	" "	1st Trial.	0·89	·6220	762	48,874	·77s	·4657
1509	" "	2d "			790	50,145	·65f	·3318
1510	**LOWMOOR.**		1·00	·7854	1333	59,071	·72f	·4071
1511	" "		"	"	1047	48,874	·72f	·4071
1512	" "		"	"	1047	48,874	·89s	·6220
1513	" "		"	"	1047	48,874	·70f	·3848
1514	" "		"	"	990	46,842	·91s	·6504
1515	" "		"	"	933	44,810	·92s	·6650
1516	" "		"	"	990	46,842	·89s	·6220
1517	" "		"	"	1047	48,874	·72f	·4071
1518	" "		"	"	1276	57,039	·92s	·6650
1519	" "	1st Trial.			933	44,810	·93s	·6808
1520	" "	2d "	"	"	1047	48,874	·72f	·4071
1521	**BOWLING** (softest bar.)		1·00	·7854	1047	48,874	·89s	·6220
1522	**GLASGOW** B. Best.	1st Trial.	1·00	·7854	705	36,682	·96s	·7238
1523	" "	2d "			876	42,778	·88s	·6082
1524	" "	3d "			990	46,842	·75f	·4417
1525	" "	1st "	0·99	·7698	933	45,718	·91s	·6504
1526	" "	2d "			933	45,718	·75f	·4417
1527	" "	1st "	1·00	·7854	1047	48,874	·93s	·6808
1528	" "	2d "			1047	48,874	·87s	·5945
1529	" "		"	"	1104	50,906	·87f	·5945
1530	" "		"	"	1276	57,038	·98f	·7543
1531	" "		0·98	·7543	1161	55,121	·92f	·6650
1532	" "		"	"	1047	50,890	·80f	·5026
1533	" "		"	"	1047	50,890	·72f	·4071
1534	" "		"	"	962	47,734	·72f	·4071
1535	" "		"	"	933	46,658	·87s	·5945
1536	Do. Do.	To observe the effects from difference in the Temperature off 1 Bar.	0·75	·4417	478	50,835	·57f	·2552
1537	Temperature		"	"	464	49,948	·66s	·3421
1538	64° Fah.		"	"	450	49,060	·68s	·3632
1539	Do. Do.		0·75	·4417	478	50,835	·56f	·2462
1540	Exposed all night to intense frost,		"	"	450	49,060	·58f	·2642
1541	and broken in the morning,		"	"	435	48,109	·67s	·3526
1542	Thermometer 23° Fah.		"	"	421	47,222	·71s	·3958
1543	**GLASGOW** B. Best.		0·75	·4417	534	54,385	·63f	·3116
1544	" "		"	"	478	50,835	·59f	·2734
1545	**BAGNALL** ✠ **J B**		1·25	1·2271	1789	48,213	1·21f	1·1499
1546	**CRANK-SHAFT** B cut out lengthway, turned.		1·00	·7854	761	38,678	·90f	·6362
1547	" " " " "		1·01	·8012	704	35,923	·89f	·6220
1548	" " " " "		"	"	676	34,945	·95s	·7088
1549	" " " " "		"	"	647	33,931	·95s	·7088
1550	" " " " "		"	"	590	31,939	·98f	·7543

IS. TABLE T.

. Apparatus in XVI.

hose marked *S.*, which were received from the Makers.

N, h of in	GRADUALLY APPLIED BREAKING STRAIN.		Sudden Strain in per cent. of Gradual Strain	REMARKS.	FRACTURE,	
					Crys.	Kind
11.	12.	13.	14.	15.	16.	17.
℔ ct.	No.	lbs.	℔ ct.		℔ cent.	
42·8	136	56,004	108·6	Broke gradually, very warm.	0r	L
44·0	134	57,787	105·3	Do. do. do.	0r	L
41·8	136	56,004	89·1	Do. very slowly, do.	0r	L
39·5	134	57,787	84·6	Unbroken.	—	—
38·4	137	59,998	95·1	Broke gradually, very warm.	0r	M
40·8	138	59,570	88·9	Do. do. do.	0r	M
8·3	147	61,714	79·2	Broke quickly, Fracture same as 147.	60	X
19·0	146	62,344	78·4	Unbroken, lengthened ·011 inch in 3 hours.	—	—
26·0	146	62,344	80·4	Broke gradually.	0	Q
25·6	106	62,635	94·4	Broke gradually.	0	P
21·7	108	59,320	82·4	Do. do.	0	P
22·9	"	"	82·4	Unbroken, resting on block.	—	—
28·6	"	"	82·4	Broke gradually.	0	P
21·3	"	"	79·0	Unbroken.	—	—
19·7	"	"	75·5	Unbroken, no perceptible increase in 41 hours.	—	—
12·2	106	62,635	74·8	Unbroken.	—	—
15·3	107	60,069	81·3	Broke very gradually	0	P
20·4	105	65,166	87·5	Resting on block, dropped accidentally.	—	—
15·9	107	60,069	74·6	Unbroken, no perceptible decrease with strain off.	—	—
31·3	"	"	81·3	Broke very gradually.	0	P
22·4	124	58,678	83·3	Unbroken.	—	—
10·1	215	59,569	61·6	Unbroken.	—	—
22·4	"	"	71·8	Unbroken.	—	—
28·3	"	"	78·6	Broke.	0	S
17·6	217	56,121	81·4	Unbroken, resting on block.	—	—
25·6	"	"	81·4	Broke.	0	S
14·8	214	59,569	82·1	Unbroken, resting on block.	—	—
23·5	"	"	82·1	Unbroken.	—	—
12·4	213	60,817	83·7	Broke gradually.	18	U
3·5	"	"	93·8	Broke instantaneously.	100	Y
8·0	216	58,351	94·5	Broke suddenly.	72	U Y
13·0	"	"	87·2	Broke.	0	S
26·7	"	"	87·2	Broke.	0	S
25·5	"	"	81·8	Broke very slowly.	0	S
14·8	"	"	80·0	Unbroken.	—	—
17·2	1091	55,717	91·2	Broke.	0	S
17·5	"	"	89·6	Unbroken.	—	—
15·8	"	"	88·0	Unbroken.	—	—
19·0	1091	55,717	91·2	Broke.	0	S
17·4	"	"	88·0	Broke.	0	S
13·7	"	"	86·3	Unbroken.	—	—
11·5	"	"	84·7	Unbroken.	—	—
22·0	1094	56,604	97·8	Broke.	22	U
26·0	"	"	90·0	Broke gradually.	0	S
9·6	703	54,731	88·1	Broke suddenly after stretching.	100	Y
21·9	783 788	43,759 mean	88·4	Broke.	96	c g
8·1			82·1	Broke.	35	c
5·7			79·8	Unbroken.	—	—
6·1			77·5	Unbroken.	—	—
0·0			73·0	Broke, local flaw.	0	

TABLE V.

FOR CONVERTING THE STRAINS FROM LBS. INTO TONS.

Tons.	Lbs.	Tons.	Lbs.	Tons.	Lbs.	Tons.	Lbs.	Tons.	Lbs.	Tons.	Lbs.
1	2,240	**17**	38,080	**33**	73,920	**49**	109,760	**65**	145,600	**81**	181,440
¼	2,800		38,640		74,480		110,320		146,160		182,000
½	3,360		39,200		75,040		110,880		146,720		182,560
¾	3,920		39,760		75,600		111,440		147,280		183,120
2	4,480	**18**	40,320	**34**	76,160	**50**	112,000	**66**	147,840	**82**	183,680
¼	5,040		40,880		76,720		112,560		148,400		184,240
½	5,600		41,440		77,280		113,120		148,960		184,800
¾	6,160		42,000		77,840		113,680		149,520		185,360
3	6,720	**19**	42,560	**35**	78,400	**51**	114,240	**67**	150,080	**83**	185,920
¼	7,280		43,120		78,960		114,800		150,640		186,480
½	7,840		43,680		79,520		115,360		151,200		187,040
¾	8,400		44,240		80,080		115,920		151,760		187,600
4	8,960	**20**	44,800	**36**	80,640	**52**	116,480	**68**	152,320	**84**	188,160
¼	9,520		45,360		81,200		117,040		152,880		188,720
½	10,080		45,920		81,760		117,600		153,440		189,280
¾	11,640		46,480		82,320		118,160		154,000		189,840
5	11,200	**21**	47,040	**37**	82,880	**53**	118,720	**69**	154,560	**85**	190,400
¼	11,760		47,600		83,440		119,280		155,120		190,960
½	12,320		48,160		84,000		119,840		155,680		191,520
¾	12,880		48,720		84,560		120,400		156,240		192,080
6	13,440	**22**	49,280	**38**	85,120	**54**	120,960	**70**	156,800	**86**	192,640
¼	14,000		49,840		85,680		121,520		157,360		193,200
½	14,560		50,400		86,240		122,080		157,920		193,760
¾	15,120		50,960		86,800		122,640		158,480		194,320
7	15,680	**23**	51,520	**39**	87,360	**55**	123,200	**71**	159,040	**87**	194,880
¼	16,240		52,080		87,920		123,760		159,600		195,440
½	16,800		52,640		88,480		124,320		160,160		196,000
¾	17,360		53,200		89,040		124,880		160,720		196,560
8	17,920	**24**	53,760	**40**	89,600	**56**	125,440	**72**	161,280	**88**	197,120
¼	18,480		54,320		90,160		126,000		161,840		197,680
½	19,040		54,880		90,720		126,560		162,400		198,240
¾	19,600		55,440		91,280		127,120		162,960		198,800
9	20,160	**25**	56,000	**41**	91,840	**57**	127,680	**73**	163,520	**89**	199,360
¼	20,720		56,560		92,400		128,240		164,080		199,920
½	21,280		57,120		92,960		128,800		164,640		200,480
¾	21,840		57,680		93,520		129,360		165,200		201,040
10	22,400	**26**	58,240	**42**	94,080	**58**	129,920	**74**	165,760	**90**	201,600
¼	22,960		58,800		94,640		130,480		166,320		202,160
½	23,520		59,360		95,200		131,040		166,880		202,720
¾	24,080		59,920		95,760		131,600		167,440		203,280
11	24,640	**27**	60,480	**43**	96,320	**59**	132,160	**75**	168,000	**91**	203,840
¼	25,200		61,040		96,880		132,720		168,560		204,400
½	25,760		61,600		97,440		133,280		169,120		204,960
¾	26,320		62,160		98,000		133,840		169,680		205,520
12	26,880	**28**	62,720	**44**	98,560	**60**	134,400	**76**	170,240	**92**	206,080
¼	27,440		63,280		99,120		134,960		170,800		206,640
½	28,000		63,840		99,680		135,520		171,360		207,200
¾	28,560		64,400		100,240		136,080		171,920		207,760
13	29,120	**29**	64,960	**45**	100,800	**61**	136,640	**77**	172,480	**93**	208,320
¼	29,680		65,520		101,360		137,200		173,040		208,880
½	30,240		66,080		101,920		137,760		173,600		209,440
¾	30,800		66,640		102,480		138,320		174,160		210,000
14	31,360	**30**	67,200	**46**	103,040	**62**	138,880	**78**	174,720	**94**	210,560
¼	31,920		67,760		103,600		139,440		175,280		211,120
½	32,480		68,320		104,160		140,000		175,840		211,680
¾	33,040		68,880		104,720		140,560		176,400		212,240
15	33,600	**31**	69,440	**47**	405,280	**63**	141,120	**79**	176,960	**95**	212,800
¼	34,160		70,000		105,840		141,680		177,520		213,360
½	34,720		70,560		106,400		142,240		178,080		213,920
¾	35,280		71,120		106,960		142,800		178,640		214,480
16	35,840	**32**	71,680	**48**	107,520	**64**	143,360	**80**	179,200	**96**	215,040
¼	36,400		72,240		108,080		143,920		179,760		215,600
½	36,960		72,800		108,640		144,480		180,320		216,160
¾	37,520		73,360		109,200		145,040		180,880		216,720

TABLE U.

SPECIFIC GRAVITIES.

Names of the Makers or Works.	Table and Number.	Water = 1·0000.	
ROLLED IRON BARS.			
Farnley.	Table B. 131	7·7696	7·7600
” ”	129	7·7619	
” ”	130	7·7608	
” ”	132	7·7546	
◇ Govan ◇	711	7·7337	7·7201
” ”	712	7·7247	
” ”	709	7·7114	
” ”	710	7·7106	
Do. Do.	725	7·7134	7·6975
” ”	728	7·7016	
” ”	727	7·6927	
” ”	726	7·6823	
Bradley ♛ S C	145	7·6926	7·6887
” ”	148	7·6847	
Govan Ex. B. Best.	166	7·6980	7·6825
” ”	165	7·6851	
” ”	167	7·6849	
” ”	168	7·6618	
Glasgow B. Best.	744	7·6755	7·6578
” ”	743	7·6666	
” ”	742	7·6600	
” ”	741	7·6291	
Do. Do.	729	7·6951	7·6530
” ”	730	7·6506	
” ”	731	7·6435	
” ”	732	7·6229	
Port-Dundas Ex. B. Best.	765	7·6568	7·6494
” ”	770	7·6419	
Lord Ward L ♛ W R O	153	7·6935	7·6401
” ”	156	7·5867	
Thorneycroft T N S	149	7·6359	7·6140
” ”	151	7·6100	
” ”	150	7·6082	
” ”	152	7·6020	
* Govan. *	197	7·6313	7·6079
” ”	199	7·6145	
” ”	198	7·6040	
” ”	200	7·5818	
Bagnall ♛ J B	703	7·6306	7·5988
” ”	704	7·5978	
” ”	702	7·5908	
” ”	701	7·5760	
Dundyvan.	745	7·5790	7·5563
” ”	746	7·5639	
” ”	747	7·5482	
” ”	748	7·5340	
Do. Do.	753	7·5596	7·5464
” ”	756	7·5333	
Govan Puddled.	771	7·5381	7·4499
” ”	772	7·5217	
” ”	773	7·4296	
” ”	774	7·3102	
Ystalyfera Puddled.	779	7·4709	7·4053
” ”	781	7·4458	
” ”	780	7·4149	
” ”	782	7·2898	

TABLE U.

SPECIFIC GRAVITIES.

Index No.	Names of the Makers or Works.		Table and Number.		Water = 1·000.	
	TILTED BARS.					
1657	Swedish R F		Table B.	264	7·8067	7·7986
1658	" R F			265	7·8020	
1659	" R F			267	7·8011	
1660	" R F			266	7·7847	
1661	Do. OC			803	7·7997	7·7733
1662	" ΣO			805	7·7658	
1663	" ΣΣW			804	7·7544	
1664	Russian OOND			272	7·8088	7·7580
1665	" OOND			274	7·7445	
1666	" IOPS			806	7·7206	
	HAMMERED.					
1667	Crank-shaft A.			288	7·6585	7·6307
1668	" "			291	7·6545	
1669	" "			289	7·6250	
1670	" "			293	7·6217	
1671	" "			292	7·6170	
1672	" "			290	7·6077	
1673	Armour-plate.			797	7·6303	7·6134
1674	" "			802	7·5965	
	MISCELLANEOUS.					
1675	Govan, Hammered-bar.	&.	Table N.	1117	7·7652	7·7641
1676	" "	&.		1118	7·7630	
1677	◇ Govan ◇ Rolled-bar. All cut off *one* bar 1½ in. diameter, and after reheating rolled down to 1¼, 1, ¾, ½, to note the effects of additional rolling.	&.		—	7·7300	
1678		S.		1113	7·7290	
1679		S.		1114	7·7222	
1680		&.		1115	7·7018	
1681		S.		1116	7·6850	
1682	Bowling, Rolled-bar, ordinary condition.		B	124	7·7630	
1683	" " stretched.		T	1521	7·7093	
1684	Lowmoor, Do. ordinary condition.		B	108	7·7470	
1685	" " stretched.		T	1514	7·6605	
1686	" " stretched.		T	1512	7·6576	
1687	Blochairn Best, Do. ordinary condition.	S.	Table N.	1090	7·6360	
1688	" " stretched.	S.		—	7·5829	
1689	" " stretched.	&.		—	7·5553	
1690	Do. Do. cold-rolled.	&.		1081	7·5797	7·5824
1691	" " " "	&.		1082	7·5805	
1692	" " " "	S.		1084	7·5824	
1693	" " " "	&.		1086	7·5868	
	ANGLE-IRON.					
1694	Farnley.		Table E.	669	7·7310	7·7280
1695	" "			672	7·7250	
1696	Consett Best Best.			663	7·6344	7·6333
1697	" "			668	7·6322	
1698	Glasgow Best Best.			644	7·5740	7·571
1699	" "			647	7·5689	
1700	Albion Best.			651	7·5460	7·539
1701	" "			653	7·5338	
1702	Dowlais.			622	7·5318	7·530
1703	" "			625	7·5297	

TABLE U.

SPECIFIC GRAVITIES.

Names of the Makers or Works.		Table and Number.		Water = 1·0000.	
IRON PLATES.					
FARNLEY.	S.	Table D.	442	7·7419	7·7322
" "	S.		445	7·7226	
LOWMOOR.			401	7·7008	7·6990
" "			410	7·6972	
◇ GOVAN. ◇			968	7·6813	7·6750
" "			973	7·6686	
CONSETT Best Best.			911	7·6312	7·6199
" "			863	7·6262	
" "			887	7·6245	
" "			920	7·6236	
" "			921	7·6142	
" "			910	7·6130	
" "			930	7·5969	
" "			886	7·5720	
WELLS ♔ Best Best.	S.		946	7·6269	7·6185
" "	S.		957	7·6100	
SNEDSHILL ♔ Best.			931	7·6128	7·5802
" "			940	7·5476	
WELLS ♔ Best Best.			479	7·5727	7·5706
" "			487	7·5685	
GLASGOW Best Best.			551	7·5748	7·5414
" "			573	7·5586	
" "			590	7·5427	
" "			854	7·5398	
" "			572	7·5319	
" "			561	7·5005	
BLOCHAIRN Best.	Usual state. S.	Table O.	1137	7·5658	7·5664
" "	" " S.		1140	7·5669	
Do. Do.	Cold-rolled. S.		1135	7·5403	7·5392
" "	" " S.		1138	7·5381	
STEEL PLATES.					
NAYLOR, VICKERS, & Co.	Cast-steel, S.	Table C.	309	7·8280	7·8253
" "	" " S.		320	7·8226	
MOSS & GAMBLES.	Do. Do. S.		330	7·8242	7·8220
" "	" " S.		321	7·8198	
TURTON & SONS.	Do. Do. S.		308	7·8194	7·8152
" "	" " S.		301	7·8110	
SHORTRIDGE & Co.	Homo. Metal.		335	7·8093	7·8090
" "	" "		331	7·8064	
" "	" "		340	7·7997	
" "	" "		341	7·7920	
Do. Do.	Pud. Steel, S.		342	7·7010	7·6829
" "	" " S.		344	7·6648	
BLOCHAIRN.	Do. Do. S.		367	7·6746	7·6672
" "	" " S.		376	7·6598	
Do. Do.	Do. Do.		377	7·6512	7·6400
" "	" "		380	7·6287	
STEEL BARS.					
JOWITT's Cast-steel for Chisels.		Of Bars in the ordinary condition, and not forged down, as were those in Table A.		7·8308	7·8232
" " "				7·8256	
" " "				7·8205	
" " "				7·8162	
BESSEMER's Patent steel for Tools.	S.			7·8224	7·8207
" " "	S.			7·8222	
" " "	S.			7·8209	
" " "	S.			7·8175	
WILKINSON's Ⓛ Blister-steel.				7·7327	7·7200
" " "				7·7218	
" " "				7·7150	
" " "				7·7083	
BLOCHAIRN Puddled-steel.				7·7345	7·7070
" " "				7·7229	
" " "				7·7007	
" " "				7·6698	

APPENDIX.

A.

Editorial Article in *The Engineer*, *22nd February*, 1861.

Strength of Iron.

"The value of one description of iron, as compared with that of another, should, it is to be supposed, depend upon its comparative strength. There are cases, it is true, where cast-iron is employed as much for its mere weight as anything else, inertia, or the stability of ponderosity, being of more consequence than absolute strength. For such purposes lead would, of course, be preferable to iron, could it be had at the same price. But in a majority of the applications of iron, its own weight is a load, *pro tanto*, upon its power of resistance, and in bridges it is easy to calculate the span at which the structure would be destroyed by its own gravity. If, then, there were one invariable standard of cohesive power in all iron, or if it required, let us suppose, ten tons to pull asunder one square inch of cast-iron, and twenty-five tons to part a similar section of wrought-iron—no matter of what make—our whole practice of construction in iron would stand in a very different position from what it now does. From the data contained in the majority of our engineering books, it might be supposed that this uniformity of strength actually existed. Many engineers assert that 'there is no great difference in iron,' and their practice is apparently conducted upon this assumption. Mr. Robert Stephenson assured the Iron Commission of 1848 that there was not probably a greater range than five, six, or seven per cent. either way from the medium strength of all the irons in this country. The same distinguished engineer, however, sent in to the Commission a table of experiments made under his authority to determine the iron best suited to the construction of the High Level Bridge at Newcastle, and of the large number of 1-inch square bars tested on 3 feet supports, the transverse breaking weight varied all along from 518 lbs. to 1,072 lbs., the average being something like 800 lbs. or 850 lbs. Thus, of ninety-six specimens, three bore between 500 lbs. and 600 lbs., one between 600 lbs. and 700 lbs., nineteen from 700 lbs. to 800 lbs., thirty-four from 800 lbs. to 900 lbs., twenty-eight from 900 lbs. to 1,000 lbs., whilst eleven specimens bore more than 1,000 lbs. The Government experiments, completed last year at Woolwich, comprised 850 samples of cast-iron, all sent in for a competition which was to determine the best iron for ordnance, and in which it is probable that every one sending samples selected such as he believed to be his best. These experiments, as is known, disclosed tensile strengths varying from 9,417 lbs. to 34,279 lbs per square inch, the results ranging variously from nearly 14,000 lbs. under to 11,000 lbs. above the general average. The strongest iron was, therefore, 3⅝ times as strong as the weakest iron. Then, again, there are Messrs. Napier & Sons' experiments, carried out more than a year ago at Glasgow; of 90 cast and puddled-steel bars, the range of tensile strength was from 148,294 lbs. down to 42,564 lbs. per square inch. Of 195 wrought-iron bars, the strength varied from 68,848 lbs. to 44,453 lbs. Eighty steel plates ranged from 108,906 lbs. to 62,435 lbs., and 150 iron plates showed a range of tensile strength from 62,544 lbs. to 32,450 lbs. Of thirty samples of Acadian charcoal cast-iron, tested in December, 1858, at Woolwich, the tensile strength varied from 43,928 lbs. down to 15,071 lbs. per square inch, the variation in strength being, as in all the other experiments referred to, promiscuous, and with no apparent tendency to any general standard. In Lloyd's experiments on rivetted iron ship plates, made some time since at Woolwich, some of the butt straps opened at a strain of but about 4 tons per square inch of actual cross-section, and the ⅜-inch plate parted generally at from 5 to 10 tons per square inch of solid iron. After the fatal explosion of a locomotive boiler, in 1858, at an engineering establishment in Manchester, Mr. Fairbairn tested several of the plates, one of which broke under a strain of 4⅔ tons per square inch.

"Those familiar with iron are aware that bars and plates are occasionally met with which, upon a blow from a hammer, will break like cast-iron. It is the same with railway bars, some of which can hardly be broken under the severest tests, while others are found, now and then, to break by their own weight in dropping upon the ground. It is but fair to admit that iron of any particular 'make,' especially if the product of long-established works, is not likely to exhibit the wide range of strength indicated in the results to which we have referred, but except for special applications, or where very large quantities are employed, the iron is generally anonymous, and difficult of identification.

"It is owing to the great range of quality that iron subjected to strain cannot generally be trusted beyond from one-fourth to one-sixth of its calculated ultimate strength. Engineers will proportion bridges which, upon a calculation of strength, will show six times that necessary to bear the heaviest load to which they will ever be subjected in practice, but the calculation is based upon the assumption that the iron is of a certain uniform strength; whereas its strength is so variable that, with the supposed excess of metal, one or more important members of the structure may be barely able to sustain themselves under continued strain. No piece of iron can be said to have a certain strength until that strength has been ascertained by trial, and the trial must be such as to destroy the iron. It is thus that failures of bridges, boiler explosions, fractures of chain-cables, &c., prove iron to have had, perhaps, but one-third or one-sixth the strength at which it had been estimated. Such disasters do not probably exceed in number one or two per cent. of all the applications of iron in which they occur,—not more than one or two boilers exploding out of every hundred made and set to work. A moderate observation, however, of the variable nature of iron will show, we think, that of every hundred samples, one or two are below the safe limits of strength, whilst, to all appearance, they may be as strong as the best. These facts point to the necessity of the utmost care in the selection of iron for every application in which unquestionable strength is indispensable, and this selection can be only partially fulfilled even by regarding manufacturers' brands. More frequent actual tests of iron, involving the destruction of at least one of every hundred separate pieces to be put in use, are necessary. With these tests, and taking into account the value of the iron after having been broken, a saving considerably greater than the whole cost of trial might doubtless be made by slightly lowering the multiple of strength to the standard which such trials would finally establish, our constructions in iron being, even then, demonstrably safer than they now are when the actual strength of the materials used is so variable."

B.

EXTRACTS FROM LETTERS OF "AMICUS" TO *The Times* OF 1*st November and* 6*th December*, 1859,

In Reference to the Loss of the "Royal Charter."

"It would seem to commend itself to the common sense of every man that in building an iron sailing or steam-ship, which is to be subjected to all the strains and buffetings of tempest-tossed seas, which will be freighted with hundreds of human beings and the most precious cargoes, and which must run the risks of collisions and strandings, none other than the very best and strongest materials should be employed. The toughest iron, the best seasoned spars, and the stoutest planks and ropes should alone find places in such a venture. But in our ordinary everyday practice is this the case? Is not any kind of iron thought good enough to build a ship with? What is the meaning of 'boat plates' being the lowest priced in any ironmaker's list? If we pay £25 or £30 a-ton for the plates of which a locomotive boiler is made, why should we give only £8 10s. or £9 per ton for those of which a ship is built? If safety can only be bought at the high price in one case, are we not courting disaster with the low price in the other? Who will draw the fine line of distinction in moral responsibility between the directors of a railway company who should take your fare, place you in a comfortable first-class carriage, and drive you at forty miles an hour over a viaduct which was miserably insecure, and the owners of vessels who send passengers to sea in ships sheathed with plates which are as brittle as glass? The only answer to this question in the way of excuse is, I fear, that most men are really and truly ignorant of the facts. In the eyes of the merchant of London or Liverpool who orders the building of a ship, iron is iron. He probably does not know that in this material there are as many shades of quality as there are in the wines or fruits which all bear one common name; and yet I am within mark when I say that he might, by paying £2 or £3 per ton increased price upon the plates forming the outward sheathing of his ship, immensely increase the vessel's strength and durability.

"With good well-worked plates, where the fibre of the iron is ductile and tenacious, and where these plates are well and judiciously fastened together, no vessel, even if wrecked in such a gale as that of last Tuesday, would break to pieces so suddenly and so utterly as the 'Royal Charter' seems to have done.

"But built of the 'boat plates' of the present day, God help the human freight of the ship that strikes upon a rocky shore !

"I would therefore advise shipowners, when contracting for new vessels, instead of being satisfied with a specification which provides good ordinary 'boat plates' to be used, and which are, in fact, about the most rubbishing quality of iron which is made, to insist that the sheathing should all be of the best or double-worked quality. In a vessel of 1,000 tons it would not increase the cost £500, and the value is gained in the greater strength and durability of the ship, to say nothing of the lives it may possibly save.

"Further, I would caution all well-disposed shipowners to look with great suspicion upon the cheap offers which are constantly laid before them as temptations to order ships. To any one conversant with a ship's value, what other construction can be put upon a contract for a vessel of 1,000 tons, with the most expensive outfit, for £13. or £13 10s., or even £14 per ton measurement, ready for sea, than that the builder means to employ bad materials and scamp his work? He begins upon such an order with a determination either to cheat his customer or cheat his creditors."

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"Upon the evidence brought before the two tribunals* the decisions could not have been different. But if that evidence had been made more comprehensive; if the captain or others in authority had been saved to tell us of the ship's behaviour in heavy weather; if we had had more general and extensive tests of the strength of the ship's material; if some calculations had been furnished of her strength, considering her hull as a beam supported in the middle and unsupported at its ends, which must have been very nearly the ship's position when she parted amidships; and if we had been informed whether the plates used in her construction were really 'boat plates,' or 'best plates,' *and where they had been made*, the public would have been inclined to attach greater importance to the conclusions arrived at. If I may be permitted the paradox, iron is not always iron. It is sometimes rubbish, and in this category I would unhesitatingly place all 'boat plates.' It is not that even in these inferior plates pieces may not be found which shall come up to and even surpass Mr. Fairbairn's standard of the average tenacity of good Staffordshire plate; but, being made chiefly from cinder iron, it is their *inequality* and *uncertainty* which is most to be dreaded. The strength of the whole is that of the weakest part, and when I tell you that out of the same 'boat plate,' or iron of that quality, two pieces have been taken, one of which sustained 22 tons to the square inch of section, while the other failed at 5 tons, I have said enough to show why this dangerous material should be at once discarded in building ships, and the price of 'best plates' be paid to insure the exclusion of cinder iron from their manufacture. Boat plates are shams. They are got up to deceive by appearances. Smooth and well-looking on the surface, the source of mischief lies hidden underneath—rotten at the core, like the grub-eaten fruit whose tempting skin conceals the tiny hole by which the insect has entered. But this iron is a curse as well as a deception, for while you may be angered at the Yankee who has sold you wooden nutmegs, or the grocer who sands his sugar, or the petty swindler who sells you 100 yards of sewing cotton 'warranted' 200, I know no words strong enough to condemn the practice of makers and buyers alike, who, in structures where the safety of life and limb is at stake, will willingly and knowingly, and for gain's sake alone, imperil the existence of their fellow creatures."

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* Coroner's Inquest and Board of Trade Inquiry.

C.

EXTRACT FROM A PAPER READ BEFORE THE SCOTTISH SHIPBUILDERS' ASSOCIATION, *4th February*, 1861, BY J. G. LAWRIE, Esq.

On Lloyd's Rules for Iron Ships and their Improvement.

"There is no doubt of the superior toughness and tenacity of Lowmoor iron; and the advantage of using it in the construction of ships is obviously much greater than the relative superior tensile strength which it possesses over ship iron. A ship placed, for example, in the positions shown in the diagrams (for which see paper), receiving a blow from a sea on the exposed part of the side, sustains a tremulous or vibratory shock, for which the toughness and tenacity of Lowmoor iron is admirably adapted. Experiments have not been made to ascertain the exact superiority of Lowmoor iron for such work; but if it be assumed to be twice as strong as ordinary ship iron, it can be shown that the quantity of material in the frames, floors, beams, &c., would be reduced 50 per cent., and in the skin plates, stringers, &c., 30 per cent. With a material three times as strong as ship iron, which the manufacturers of steel state it to be, the weight of the frames, floors, and beams is reduced 66 per cent., and the skin plates, stringers, &c., 42 per cent. With this reduced weight in the hull of a ship the displacement is reduced; and if the speed is to be retained at the same rate, the power of the engines and weight of coal carried is reduced, which involves a further reduction in the displacement, and that again a further diminution of power. So that reducing the weight of the hull by the use of improved material involves a reduction in the weight of the engines, coal, &c., and a reduction in the displacement of the ship, due both to the diminution in the weight of the ship and to the diminution in the power of the engine; or if the weight of the cargo and speed be retained of the same amount, the use of improved material permits a reduction in the size of the ship, to perform the same amount of work. To show[*] the effect of this in practice, a ship of 1,500 tons N. M., fitted with engines of 200 H. P., weighing 200 tons, and carrying 400 tons of coal, has a displacement of say 2,610 tons; and if built of iron, the weight of hull will be about 1,080 tons. The weight of cargo will therefore be 2,610 tons, less 1,680 for the weight of the hull, machinery, and coal—giving a net cargo of 930 tons at the draught of water assumed. The weight of iron in the hull of this ship would be 867 tons. A ship of 1,080, proportioned in dimensions and form as the 1,500 ton ship, has a displacement of 1,880 tons; the weight of hull, if built of steel three times as strong as iron, will be 468 tons; the power to propel her at the same speed as the 1,500 ton ship will be 160 H. P., and the coal for the same time of voyage, 320 tons; therefore the weight of cargo will be 932 tons, the same as the 1,500 ton ship. The weight of steel in the hull of this ship would be 315 tons. The cost of the 1,500 ton ship, at £18 for the hull, and £40 for the machinery, would be £35,000. The cost of the ship 1,080 tons, at the same prices, would be £25,840; to which add £3,200 for the difference betwixt 315 tons of steel, at £30 per ton, and 625 tons of iron (the quantity that would be in the ship, if built of iron), at £10 per ton, and the price of the ship is £29,040.

"Thus, a ship of 1,080 tons N. M., built of steel having a strength equal to three times that of iron, and at the price of £30 per ton, will carry the same cargo as a ship of 1,500 tons N. M., built of iron, will steam at the same rate, and for the same length of time. The advantage in the use of this material, if the statement about the strength be correct, is therefore not only that a ship, to carry at a given speed a given weight of cargo, costs less money in the proportion of £29,000 to £35,000, but in the proportion of the smaller tonnage and power of machinery costs less in current outlay."

"It would obviously be injudicious, either for shipbuilders or shipowners, and still more so for the Committee of Lloyd's, to receive, without question or hesitation, the statements made by the makers of improved material; but plainly the material is of some considerable strength. A considerable number of sensible men urge its introduction on grounds which, if true, are highly useful, and it does not appear that Lloyd's Committee would travel too far if they stated on what conditions and on what experiments, made at the expense of those who urge the introduction of the material, they would consent to give it a stipulated standing in their books. To do this they are not disposed, and there the matter for the present rests."

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[*] "Put $T =$ tonnage; $D =$ total displacement; $a\,D =$ displacement due to weight of ship built of iron; $b\,D =$ displacement due to weight of machinery, coals, &c; $\therefore$ weight of cargo $= D - a\,D - b\,D = D\,(1 - a - b)$; $c \times a\,D =$ displacement due to weight of ship built of steel; $D' =$ displacement of smaller ship built of steel.

By the formula $A = \dfrac{V^3 \times D^{\frac{2}{3}}}{\text{Ind. H.P.}}$; $D^{\frac{2}{3}} : D'^{\frac{2}{3}} :: b \times D : b\,D \times \dfrac{D'^{\frac{2}{3}}}{D^{\frac{2}{3}}}$

$D' = D\,(1 - a - b) + c \times a + D' + b\,D \times \dfrac{D'^{\frac{2}{3}}}{D^{\frac{2}{3}}} \therefore D'\,(1 - a\,c) - b\,D \times \dfrac{D'^{\frac{2}{3}}}{D^{\frac{2}{3}}} =$ $D\,(1 - a - b)$. Put $D = 1$, and $D'\,(1 - a\,c) - b\,D'^{\frac{2}{3}} = 1 - a - b$.

"If $T = 1$ N. M., $D = 1{\cdot}74$, $a\,D = 0{\cdot}72 = \{$(sundries $= 0{\cdot}142$) + (floors, frames, and beams $= 0{\cdot}178$) + (skin plates, stringers, &c., $= 0{\cdot}4$)$\}$ for iron, $c \times a\,D = 0{\cdot}433 = \{$(sundries $= 0{\cdot}142$) + (floors, frames, and beams $= 0{\cdot}0593$) + (skin plates, stringers, &c. $= 0{\cdot}232$)$\}$ for steel three times as strong as iron. In the ship of 1,500 tons, referred to in the text, $b\,D = 600 \therefore b = \dfrac{600}{2{,}610}$. Substitute these values in the above equation, and it becomes $D' - 0\;3057\,D'^{\frac{2}{3}} = 0{\cdot}472 \therefore D' = 0{\cdot}7197 \times D$."

D.

EXTRACT FROM EDITORIAL ARTICLE IN *The Engineer*, *8th February*, 1861.

Strength of Iron Ships.

"We suppose it to be hardly necessary to await the loss of a further number of iron ships, by opening their seams and foundering in open sea, before calling renewed attention to the necessity for better stock and sounder construction than now prevail in such vessels. When, after a protracted investigation by the Board of Trade, no definite reason can be assigned for the loss of a new steam-ship like the Connaught, for instance, it were nothing strange should the public assume that a very large number of all the iron vessels now running are in a dangerous condition, or, what is the same thing, ready to spring a leak and go down at any moment. For a ship originally unseaworthy is not necessarily lost on her first voyage, nor even in the first storm in which she may be exposed. She may, indeed, outlive a storm, afterwards to founder in a calm, as did the steamer already mentioned. This condition of uncertainty, however, which, in spite of Lloyd's surveys, and in spite of the assurances of shipbuilders, owners, and managers, actually does exist — proved as it is by frequently-recurring and most startling evidence—is one from which our iron shipping should be redeemed as fast as possible. Builders and owners are constantly protesting against interference; but it is the business of legislation and of public opinion to interfere wherever the safety of human life is concerned, and nowhere is that safety more dependent upon staunch workmanship and unwearying vigilance than in our sea-going steamers. There are calamities, it is true, which no foresight can avert, but the foundering of ships in deep water are not to be reckoned among these. A well-made, egg-ended cylindrical boiler, launched upon the sea, would undoubtedly, if not beaten upon rocks, float until its plates were eaten through by corrosion. There is no reason to suppose that, even if it were loaded until it barely floated, it would founder in any sea, however furious. Iron shipbuilding is very like boiler-making, like materials and like tools being employed, with the disadvantage, in the former case, of having irregular and naturally weak forms to deal with. It is here that science and skill have their proper field, for it is not difficult to make the ship as strong, practically, as a good job of boiler-work. This standard of strength is not too high when the consequences of weakness are considered.

"The inferior quality of the iron commonly employed is notorious. It is at least so notorious that Lloyd's Committee, in making their experiments, in 1857, on the strength of rivetted joints, purposely employed plates of a quality 'much below the standard assigned for the test of iron,' but supposed to be of the average quality used in shipbuilding. Some of the iron broke under a strain of five tons per square inch of actual cross-section, and the average was hardly above ten tons. Subsequently to the meeting of the Institution of Naval Architects, whose proceedings had an unmistakable influence at Lloyd's, the latter body added a requirement in their famous 'rules,' to the effect that all plate, beam, and angle-iron in ships intended for classification should be stamped with the maker's name and address on both sides. This is one point gained in behalf of safety, although, practically, it may not amount to a very great deal.

"But there is an extraordinary fact, upon which we are not sure whether even Mr. Fairbairn, who has given us so many sermons upon plate-iron work, has directed attention. Whilst Lloyd's experiments were made on plates only $\frac{3}{8}$ inch thick, it is necessary, in order to procure a 12 years' classification of a 3,000 ton ship to use iron $1\frac{1}{16}$ inch thick in the garboard streaks, and yet experiments have been made which appear to show that a rivetted joint of even $\frac{1}{2}$-inch iron is absolutely *weaker* than one in $\frac{3}{8}$-inch plate. Mr. Bertram's experiments, made some time back at Woolwich, showed that whilst a single-rivetted seam in a certain width of $\frac{3}{8}$-inch plate required a strain of 18 tons to fracture it, a seam of the same kind and width, but in $\frac{1}{2}$-inch iron, was torn open at 16 tons! The general deduction was, that whilst in $\frac{3}{8}$-inch plate a single rivetted joint had 60 per cent. of the full strength of the solid plate, one in $\frac{7}{16}$-inch iron had but 50 per cent., and one in $\frac{1}{2}$-inch plate but 40 per cent. of the strength of the original solid plate, a joint in $\frac{1}{2}$-inch plate being but two-thirds as strong in proportion to its thickness, and actually weaker irrespective of thickness than in a plate only one-fourth thinner! In Lloyd's experiments, furthermore, when butt straps were employed to connect the plates at the joints experimented upon, it was found that straps cut from $\frac{3}{4}$-inch plate, or bar-iron of that thickness, were practically no stronger than $\frac{3}{8}$-inch iron similarly used. That is, the plates (not the plates from which the straps were cut) being uniformly $\frac{3}{8}$ inch thick, it was found that when $\frac{3}{4}$-inch butt straps were used the fracture occurred as often through the strap as in the plate. Every worker in iron is aware that thick plate is relatively weaker than thin, but the proportion disclosed in these experiments is startling. Very few of the $\frac{3}{4}$-inch butt straps withstood more than 7 tons per square inch of actual solid section.

E.

Extract from Editorial Article in *The Engineer*, *4th July*, 1862.

Notes of the Week.

"One year ago to-day the boiler of an express engine on the London and North-Western Railway burst while running with the Irish mail train near Rugby. To-day a suit is going on at Guildhall to recover damages from the company, in favour of one of the passengers who is now paralyzed in consequence of injuries received on the occasion of the accident. The engine was made by Sharp, Stewart, and Co., and commenced running in October, 1851. It had run nine years and eight months up to the time of the explosion, and had attained a mileage of 336,368 miles. It was worked, up to the date of the explosion, at 120 lbs. per square inch, and actually exploded at 115 lbs. The boiler during the whole period of service had been internally examined but once, viz., in October, 1857, when a new set of tubes was put in. It was one of a large class, for a 16-inch cylinder engine, with 22-inch stroke and 7-feet driving wheels. The firebox contained the large extent of 142 square feet of surface, and the tubes had an external surface of 1,152 square feet. Yet this boiler, which was 4 feet 1$\frac{3}{4}$ inch in internal diameter, was made of $\frac{3}{8}$-inch Lowmoor plates, with single-rivetted joints. Mr. Fenton, the engineer of the Lowmoor Iron Company, found the strength of some of the plates, forming fragments of the exploded boiler, to be 22 tons, or 49,280 lbs. per square inch. Supposing this to have been the strength of the plates when new, the bursting strength of the boiler was only 412 lbs. per square inch; and even if, as has been stated, the original strength of the plates was 51,000 lbs., the bursting strength would be but 437 lbs. per square inch. This is assuming, what experiment and the best authorities show, that the strength of a single-rivetted seam is 56 per cent. that of the solid plate, 40 per cent. of the solid iron being actually punched out with $\frac{11}{16}$-inch rivet holes, 1$\frac{3}{4}$ inch from centre to centre, the remaining iron being somewhat injured, moreover, by the operation of punching. But 412 lbs. would be the bursting strength under hydrostatic pressure, and steam pressure, to the same extent, is believed to be even more trying, in consequence of the heat and the jolts to which the engine is subjected when running. The real factor of safety was probably not much over 3, certainly not over 3$\frac{1}{2}$. The engine, moreover, had, in less than ten years, done nearly seventeen years' work. For the last three years and eight months of its life it had run continuously at the rate of 38,000 miles a-year, without any attempt at internal examination! Need we wonder that the barrel of the boiler, after explosion, was found to have been furrowed by corrosion for a total length of nearly 8 feet along the seams of rivets, and in some places to the thickness of only one-sixteenth of an inch? Originally weak, and now over-worked, what are we to expect of other boilers of the same class? Our leading makers are now using $\frac{7}{16}$-inch or $\frac{1}{2}$-inch plates, with thickened edges and double-rivetted seams, for large locomotive boilers, and with these, and the present high pressures, the factor of safety is under 5. Until we adopt steel boilers with welded joints it will be next to impossible to make and safely work locomotive boilers a single inch larger than those now in use."

F.

EDITORIAL ARTICLE IN *The Engineer*, 11*th July*, 1862.

The Hydraulic Test for Boilers.

"In the course of a recent legal inquiry at Guildhall, a few engineers, practised in locomotive mending, expressed strong opinions against testing boilers by hydrostatic pressure. A boiler had exploded on the London and North-Western Railway, and Mr. M'Connell, late locomotive superintendent of that line, and who, if anybody was officially responsible for the disaster, was allowed to appear as a witness, and give evidence that it was imprudent to test the strength of boilers. Mr. M'Connell, too, had not a single fact to adduce in proof of the impropriety he sought to establish. He never tested his boilers—had never even seen a boiler tested—but left them to blow up whenever their untested barrels became sufficiently weakened by corrosion. Mr. Gooch, too, a gentleman who has for many years had the mending of the Great-Western engines, thought it injudicious to subject boilers to the hydraulic pump, although he could not say exactly why, except that that was his opinion. Mr. Kirtley of the Midland, and some one else, whose name we forget, was of much the same mind. These witnesses, or some of them, affected the greatest ignorance of the fact that the hydraulic test was regularly employed on other lines, where, possibly, in consequence of the test, boilers do not explode, and whereby the shareholders are not subjected to costly suits growing out of explosions. Thus, on the Eastern Counties, the South-Eastern, the Lancashire and Yorkshire, the Newcastle and Carlisle, the North British, the Caledonian, the Edinburgh and Glasgow, and other lines, both new and old boilers are regularly tested up to twice their working pressure. In France all wrought-iron steam boilers of whatever description must, by law, be tested by the hydraulic pump up to three times their working pressure, cast-iron boilers being tested up to five times their working pressure. In America all Government boilers must bear a hydraulic pressure two-thirds greater than that at which they are intended to work, and a similar test is now enforced, by the police of New York, upon upwards of 3,000 steam boilers at work in that city. Mr. Fletcher, the engineer to the Manchester Association for the Prevention of Steam Boiler Explosions, and who has occasion to examine more boilers, perhaps, than any other man living, applies and strongly recommends the hydraulic test, and so does Mr. Longridge, the engineer to the Steam Boiler Assurance Company. Many of the agricultural engine makers test their boilers also in the same manner.

"Now, does this test injure a boiler, and if not, is it a useful test? Let us see. According to the best authorities the elasticity of iron, and, therefore, iron itself, is permanently injured by a strain somewhere between one-third and one-half its breaking strength. If a locomotive boiler, the bursting strength of which is, as it should be, 800 lbs. per square inch, be tested with the force pump to 400 lbs., the chances are that the iron will be injured. If it be tested to 250 lbs. abundant experiment goes to show that no harm will be done, and the boiler will remain safe, to all intents and purposes, under a steam pressure of 125 lbs. per square inch. But we cannot know, until we have actually burst open a boiler, what its ultimate strength really is. The boiler to which, upon a general faith in the maker's stamp on the plates, and in the style of rivetting, we may assign a probable strength equal to 800 lbs. on the square inch, may contain a hidden flaw, or—as did the new boiler which burst four years ago in Messrs. Sharp, Stewart, & Co.'s workshops—a rotten plate with a strength of but 4⅜ tons per square inch, and the bursting strength may be but 150 lbs. or 200 lbs. In this case a hydrostatic pressure of 250 lbs. would search out and proclaim the defect at once. But if the flaw were such that the bursting pressure was, say, 400 lbs., then it is probable that a test of 250 lbs. would, while failing to disclose weakness, actually injure the boiler, and possibly lead to explosion. The boiler, the bursting of which led to the suit already mentioned, had an ultimate strength of somewhere about 425 lbs. only per square inch. That is to say, it was 49¾ inches in internal diameter, and it was made of ⅜-inch plates single rivetted. The original strength of the plates may be taken as 51,000 lbs. per square inch, so that, for each inch in length of the boiler, the full strength of the ¾ square inch of sectional area of iron plate, weakened to the extent of 44 per cent. at the single-rivetted joints, would be 21,420 lbs., and as the pressure would be exerted diametrically across the boiler upon a line of 49¾ inches, the quotient would be 430½ lbs. per square inch, which would be the extreme bursting strength of the barrel. That such a boiler would have been fatally injured (although, perhaps, not actually broken open) under the French hydraulic test of three times the working pressure, or 360 lbs., there can be no doubt whatever. A test of 250 lbs. would probably have been dangerous, not of course while making the test, which, even if it tear open the boiler, can do so only quietly, but dangerous on account of the injury which it would probably do to the iron, thereby predisposing to explosion afterwards. Yet we shall show that this does not support Messrs. Gooch's, M'Connell's, and Kirtley's opinions as to the impropriety of the hydraulic test; for iron is only injured by injuring its elasticity, and its elasticity is injured only when it shows, after being strained, permanent elongation of the fibres. Thus a boiler, the bursting strength of which was 430½ lbs., would unquestionably be found to have had its diameter slightly but permanently increased under a strain of 360 lbs., and in all probability under a strain of 250 lbs. So far as we are aware, the practice of measuring the diameter of boilers, under successive increments of strain, has never been initiated. Yet why should it not be begun? Take the exact diameter of the largest ring of a boiler when the interior is charged with cold water to a pressure of 100 lbs., measure it again with the pressure increased successively to 150 lbs., 200 lbs., 250 lbs., and so on possibly to 300 lbs. Then ease off the pressure, and note how much, if at all, the iron has been permanently stretched. If, at 100 lbs. pressure, or when entirely free from strain, the diameter is exactly what it was before the test, the boiler is safe with any ordinary load on the safety valves. If permanently enlarged to any considerable extent, the boiler needs immediate strengthening. To say that boilers, upon the soundness of which so much depends, should not be tested at all, does little credit either to the skill or astuteness of men like Messrs. Gooch, M'Connell, and Kirtley. Iron, in any shape upon which we may have occasion to depend, should always be tested. No engineer would think of permitting an iron bridge to be opened until it had been loaded with the greatest weight which could ever come upon it in the way of traffic. The engineer, however, does not rest satisfied with the mere discovery that his bridge is not broken down under the test, but he carefully notes the deflection of his arches or girders, and observes whether they take a permanent set, and if so, how much. The safety of the bridge is inferred, not so much from the fact that it has survived the ordeal of a load of locomotives, or of pig-iron, or ballast, but from the amount and character of its deflection. Every chain cable received into the royal navy is tested, and the action and effects of the test strain are exactly analogous to those of the hydraulic test for boilers. And just as in the case of a cable which suffers no permanent elongation under strain, we may conclude that a boiler which is not permanently distended by the hydraulic test is in no respect injured by it. This point being settled, it requires but little consideration to perceive that the test by the force pump must be a useful one. Indeed, to our mind, it is indispensable to anything like security. It may be safely, cheaply, and expeditiously applied—the oftener the better—and as long as the boiler, upon careful measurement before and after the test, shows no permanent distension, there is no fear of its bursting from weakness, original or produced. But without a pair of callipers large enough to take in the boiler, and without careful observation during and after the application of hydrostatic pressure, we should fear it might injure the boiler. The disclosures in the case of the exploded boiler of the London and North-Western engine have convinced us that there are many so-called 'first-class' engines which could not safely be submitted to any test much beyond their ordinary working pressure, and we must suppose that Messrs. Gooch, M'Connell, and Kirtley, who can hardly be ignorant of this fact, make it the sole ground of their objection to the hydraulic test."

G.

EXTRACT FROM PAPER READ BEFORE SECTION G. OF THE BRITISH ASSOCIATION, *Sept.* 1861, BY WILLIAM FAIRBAIRN, LL.D., F.R.S.

On the Effects of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Bridges and Girders.

"It is upwards of fifteen years since a series of experiments were made to determine the value of wrought-iron rivetted plates in the form of rectangular tubes, when employed as girders spanning rivers and ravines for the support of roads and railways. Those experiments led to the erection of the Conway and Britannia Bridges on the Chester and Holyhead Railway, and determined the form in which such structures should be designed, as also the strength necessary to resist the strain of the passing loads. A new theory of construction was thus developed, and a new era established in the history of bridges. Since that time some thousands of bridges, composed entirely of wrought-iron plates, have been erected, supporting roads and railways with a degree of safety not attainable with any other description of material.

"The construction of the Britannia and Conway Bridges of the tubular form led to the introduction of tubular girder, plate, and various forms of lattice bridges, all founded on the same principle.

"The tubular bridges were originally designed so that their ultimate strength should be six times the greatest rolling load which could be placed upon them, after deducting the weight of the tube. This was considered a fair margin of strength, but subsequent considerations have induced in many cases an increase of this margin of resistance to five or six times the maximum rolling load and permanent load taken together.

"Owing to the great success in the first examples of wrought-iron bridges, a great demand for them arose in every direction, and numbers were made without any regard to principle, or the laws of proportion so clearly and satisfactorily developed in the Millwall experiments. The result of this was the erection of many weak bridges, so disproportioned as to be at the point of breaking with little more than double their own weight. This, together with the bad system of contractors tendering by weight, and the employment in some cases of *bad iron and bad workmanship,* have brought discredit upon the margin of strength at first considered sufficient. No construction requires greater care, or a more minute attention to sound principles of construction, than wrought-iron girders. The lives of the public depend on the knowledge and skill of the engineer, and the fidelity of himself and the contractors in the selection of the material.

"The defective and abortive structures which followed the first successful application of wrought-iron led to doubts and fears on the part of some engineers, who contended for a margin of eight or even ten times the heaviest load, whilst others considered a much smaller surplus of strength sufficient. In the evidence given before the Commission on Railway Structures in 1848-9, this variety of opinion was fully shown. Mr. Brunel allowed the maximum load to be one-third to two-fifths of the breaking weight. Mr. Grizzel and Mr. May considered one-third sufficient; Mr. Rasbrick, Mr. Barlow, and others adopted one-sixth; Mr. Hawshaw, one-seventh; and Mr. Glynn, one-tenth. Ultimately the authorities at Whitehall appear to have decided, but upon what data is uncertain, that the maximum tensile strain on any part of a wrought-iron structure, arising from the permanent load and the greatest rolling load together, should not exceed five tons per square inch. This corresponds with a strength of at least four times the rolling load and the permanent load taken together.

"This requirement of five tons per square inch on the part of the Board of Trade appears to be founded on no fixed principle, and is far from satisfactory. It is well known that the powers of resistance to strain of wrought-iron depend very much upon the form in which it is combined, and, unless the proportion of the parts are permanently established, the five ton tensile strain may lead to error."

H.

EXTRACT FROM EDITORIAL ARTICLE IN *The Engineer*, *23rd December*, 1859.

On Railway Bridges.

"Twenty tons per square inch is believed to be about the average breaking weight of the ordinary qualities of wrought-iron; and by common consent among the majority of engineers, five tons per square inch is considered as the maximum strain to which the material of any structure like a wrought-iron bridge should be subjected. Unless there has been a very general misunderstanding upon this matter, the maximum strain of five tons per square inch should include both the strain produced by the weight of the structure itself and that produced by the greatest moving load. When an authority like Mr. Fairbairn, for example, tells us that the strength of a given bridge is six times the maximum load, his statement is generally taken to mean that the maximum strain upon the material of the bridge is but one-sixth of its ultimate strength. This appears to be a very liberal margin of strength, and quite enough to satisfy the most exacting *Inspecteur* of the *Ponts et Chaussées.* If, however, from the total breaking weight of the bridge, the weight of the structure itself be deducted, and the strength then inferred by comparing the remainder of the ultimate strength with the moving load only, the apparent margin of safety, although it may appear very wide, may be, nevertheless, very narrow. Mr. Fairbairn has calculated that, at a span of between 1,800 feet and 2,000 feet, an iron tubular bridge would be barely capable of sustaining its own weight, and hence it could carry no weight whatever. If the weight of a bridge be equal to one-third of its breaking load, an additional moving load equal to one-half the weight of the structure would increase the strain upon the material to one-half of the total strength, although the strength of the bridge, beyond supporting its own weight, would be four times the moving load."

J.

EXTRACTS FROM EDITORIAL ARTICLES IN *The Practical Mechanic's Journal*, 1*st May and* 1*st June*, 1862.

The Annealing Temperatures of Metals and Crystallization produced by Vibration.

"In the second portion of this paper (part for February, 1862) we have pointed out, with sufficient examples, the state of hopeless confusion in which the notions of our so-called 'practical men' remain to the present time, in all that refers to the crystalline aggregation of metals, and the circumstances assumed to modify it; and we have given a number of instances of metallic bodies, subjected for years to countless millions of vibrations, in proof of the fallacy of the popular opinion that vibration, *per se*, if long continued, and without any qualification as to range or extent, has any power to alter the internal arrangement of metals, or to make them brittle, or reduce their ultimate cohesion, and make them untrustworthy in use. So late as since our last part of this paper was printed, *The Times*, in one of its articles upon the Hartley Colliery beam, gives currency to just the old and average misty trash on the subject, and bases its objections to the beam having been of *cast*-iron in place of wrought upon a supposed 'well-known fact' that the former becomes gradually brittle in use, owing to vibration, as though, if such were true for cast-iron, it must not also be true, *pro tanto*, for wrought-iron. The importance of endeavouring to promulgate some clear and true notions on this subject amongst civil and mechanical engineers, and ultimately amongst the public at large, has in nowise diminished.

"We therefore propose to describe here, as completely as our limits admit—

"1st. The molecular constitution of metallic bodies as being crystalline.

"2d. The circumstances that determine the arrangement of the crystals in metallic masses in the ordinary process of working them, more especially in iron in its several states.

"3d. The circumstances and their limitations that are capable of modifying the crystalline arrangement (and with these, of course, the physical properties, such as cohesion, toughness, &c.) of metallic masses in use,—*i. e.*, exposed to various strains, blows, vibrations, &c., &c."

"So much for the crystalline system of aggregation of cast-iron. Let us now proceed to *wrought-iron*, under the guidance of the same fundamental law. When wrought-iron, in any of the usual forms of its manufacture, is fractured, its molecular structure presents itself, more or less distinctly pronounced, in one or other of three forms, or reducible to their mixture.

"1st. The mass consists of minute crystals of nearly uniform size, whose facets present themselves at all possible angles, like that of refined sugar. This *saccaroid* structure usually belongs to highly refined iron and hard steely ones. Swedish *large* bars and Lowmoor iron are examples.

"2d. The fracture consists of large, sometimes very large, lamellar spangles or plates, facets of crystalline cleavage, whose planes or directions tend to general coincidence with that of fracture. The number, size, and direction of these facets are found to vary in the same mass with the direction in which it is fractured. In all very large and heavy masses, such as great forgings, these planes of crystallization tend towards a general perpendicularity to the surfaces of external contour: *i. e., they are, upon the whole, found coincident in direction with the lines in which the heavy hammer strokes have been delivered upon the surfaces of the mass.*

"3d. The fracture (hard to produce, owing to the greater flexibility of the iron than in either of the preceding cases) presents long parallel *fibre*, or bacillary crystals running in the direction of the longest dimensions (the length) of the bar.

"This is the structure of the best rivet iron, &c., wire, &c.; it is only completely developed in small bars, best in small round ones. Large rolled bars present it mixed with the second form above, or *imperfectly* developed; and in very large masses it is never found developed at all."

"*It is and must for ever remain impossible*" [!] "to produce a regular mass of wrought-iron of large size by any process of manufacture whatever—hammering or rolling, that, *after it has become cold*, shall present an uniform fibrous texture, parallel with its longest, or with any one of its dimensions.

"We must, for brevity, again illustrate by examples,—1st. It is a fact that such changes of structure can take place at ordinary temperatures. The common process of wire-drawing is a proof of this. The slab or bar of iron from which a piece of fine piano iron wire is about to be drawn—when broken through cold, will be found probably to have a fine *saccaroid* fracture—it has *no fibre whatever*" [!]—"it is pulled again and again through the draw place—the latter exercises an enormous grip upon its circumference, and an enormous *pressure transverse to the axis* of the cylinder, *the crystals arrange themselves normal to this*, *i. e.*, in the lengthway of the wire, and as the latter elongates, they elongate with it. The iron has now become fibrous, that is, all its crystals have their principal axes—the axes of greatest elasticity, parallel with each other and with the length of the wire; and its elastic resistance to tension on the unit of section has risen from say 30 tons per square inch of the original bar to 90 or 100 tons in the wire—the change has all taken place *cold*. So also, if after the round rod of hot-rolled rivet iron has got cold, it be now subjected to the further process of *cold-rolling*, or of *wire-drawing*, (for they are both in result the same) its elastic resistance will be found greatly increased. For this there are more causes than one operative, however, but into which we cannot now enter. Suffice it to observe, that these changes are produced cold, or at ordinary temperatures; but what is there wonderful in this, if the change red-hot be once understood?"

K.

EXTRACT FROM INAUGURAL ADDRESS TO THE INSTITUTION OF CIVIL ENGINEERS, DELIVERED *14th January*, 1862,

BY JOHN HAWKSHAW, Esq., F.R.S.

"The use of iron is extending on every side. Its manufacture is also, I am glad to say, improving. There was great room for its improvement. Several processes for converting it largely into steel, or into a metal approaching steel in character, are also now in use, and promise to afford an article at a moderate price double the strength of ordinary iron. These discoveries will tend still further to extend the use of iron. Should it turn out that steel, or homogeneous iron, as it is sometimes termed, uniform in quality, and of double the strength of ordinary iron, can be manufactured in large quantities at a moderate price, and can be easily manipulated, then many things that are now with difficulty accomplished will be greatly facilitated, and some things which cannot be done at all will be rendered practicable. Bridges of greater span could be constructed. Screw-shafts, crank-axles, and other parts of steam engines, at present of unwieldy size, would, by its use, be reduced to more moderate dimensions. There seems to be no limit to the size of guns, except that of the strength of the material, and the power of welding, forging, and handling them. Cannon, as we know, have already been greatly increased in power by adopting a superior material in their construction. Could we hit upon an inexpensive mode of doubling the strength of iron, the advantages to all sorts of machinery might be equal to those that would flow from the discovery of a new metal more valuable than iron has hitherto been.

"We are, I believe, in the infancy only of discoveries in the improvement of the manufacture of steel and iron. Until lately the nature of the demand for iron rather retarded than encouraged improvements in its manufacture. Railways consumed iron in vast quantities, and railway companies cared nothing about quality. They were driven to seek a tolerably good material for engine and carriage tyres; but as it respected the vast consumption in the shape of rails, they were implicitly guided by the lowest prices. As long as this system continued, it suited the ironmaster to manufacture a cheap article in large quantities, and they therefore gave themselves no concern to establish a better state of things. But heavy engines, high speeds, and an enlarged traffic, are gradually working a change. We are beginning to find that iron of the very best quality has hardly endurance enough for rails or locomotive tyres; that there is no economy in putting down rails which require taking up again in a year or two; and, in short, that the increased strains arising from the accelerated motion of railways, steamboats, and machinery generally, are necessitating a better material.

"In marine steam engines, which have received much attention, and where great attempts have been made at perfection, paddle-shafts, crank-axles, screws, and other portions have, as before intimated, already attained an unwieldy size, and the *vis inertia* and weight of such masses of metal are of themselves no slight impediment to the improvement of steam navigation, and would be greatly obviated by the use of a stronger material.

"Fortunately for this country, just at the time that the use of iron is extending, and improvements in its manufacture are developing, fresh discoveries are made of the raw material, and men seem to stumble, as it were by accident, on new fields of iron ore in places where those mineral riches have lain dormant for centuries, to await a new era and another age, when ships, like knights of old, are to go forth to battle in complete armour, and when the civil engineer has assumed the duties which devolved on the smith and armourer of former times."

L.

EDITORIAL ARTICLE IN *The Engineer, 2nd May,* 1862.

Iron and Steel in the Exhibition.

"Upwards of 4,000 tons of castings, supplied by Mr. Barrow, of the Stavely Iron Works, in Derbyshire, besides 1,200 tons of wrought-iron supplied by the Thames Iron Works, were employed in the construction of the building of the International Exhibition. Without noting these quantities as part of the exhibition of iron and steel, we will confine ourselves to the display made in the various classes.

"Messrs. Schneider, Hannay, and Co., the eminent ironmasters, of Barrow, in North Lancashire, sent a model of their extensive hematite iron works, with which representation might be commenced the examination of the whole process of converting the crude ore into iron and steel. We can hardly do more, however, than note a portion of the objects actually exhibited under these heads.

"Perhaps the largest contribution from an English ironmaster, or firm of ironmasters, is that by the Butterley Company, near Alfreton, in Derbyshire. They exhibit, in Class 1, Section 1, the following specimens:—A solid wrought-iron deck beam, 16 inch. deep, flanges, $6\frac{1}{4}$ inch. wide, thickness, $\frac{1}{2}$ inch, and having solid knees formed whole with the beam. This is one of a lot for the new iron-plated frigate 'Achilles.' A rafter bar, rolled with four flanges, and made to the order of Messrs. Cubitt & Co., for the roofs of the new buildings in Kew Gardens. A solid wrought-iron engine beam, a single slab 31 feet 6 inch. long, 7 feet deep in the centre, $2\frac{5}{8}$ inch. thick, containing 163 superficial feet on each side, and weighing 7 tons. An armour-plate, cut to size, viz., 14 feet long, 5 feet wide, $4\frac{1}{2}$ inch. thick, and weighing 6 tons. A wrought-iron boiler-plate, 12 feet 9 inch. long, 7 feet 6 inch. wide, and $1\frac{1}{4}$ inch thick. A sample, 7 feet 3 inch. long, of a patent solid wrought-iron main girder, 3 feet deep, with flanges 12 inch. wide. Girders of the same section can be made 60 feet long if required, the upper and lower halves of the girder being rolled separately, and afterwards welded by Mr. W. Bertram's process. A sample, 4 feet long, is also given of a solid wrought-iron girder, 2 feet 6 inch. deep, and having flanges 12 inch. wide; also of a like girder, 21 inch. deep, with $6\frac{1}{4}$-inch flanges, and $\frac{1}{2}$ inch thick. Also of like girders 9 inch. deep, with $6\frac{1}{4}$-inch flanges, and $\frac{1}{2}$-inch thick, cut down to length permitted by Commissioners of the Exhibition, viz., 14 feet. Also rolled girders, 14 feet long, 10 inch. deep, and 4½-inch flanges; also a patent solid wrought-iron girder, 14 feet long, 12 inch. deep, and 6⅜-inch flanges. The exhibitors were limited by the Commissioners to a length of 14 feet, although many of the sections could be produced of any length, and the armour-plate originally intended for exhibition was 24 feet long, 6 feet wide, and 5½ inch. thick. The Butterley Company succeeded in obtaining space for a railway bar 117 feet long and 5½ inch. deep, equal in length, therefore, to more than six ordinary rails. A tension bar for a wrought-iron girder is also exhibited, 83 feet long, 12 inch. wide, and 1 inch thick. A railway carriage axle, bent cold, and a railway tank pumping engine, are also exhibited, besides a lot of sections of T and angle-iron, deck beams, &c., and specimens of the coal and ironstone from which the whole were manufactured. In Class 5, the Butterley Company also exhibit a patent solid wrought-iron girder, 60 feet long, 14 inch. deep, and having 6½-inch flanges.

"It will be borne in mind that, until within a few years, it was practically impossible to roll beams, &c., of the proportions now exhibited, while large armour-plates and wrought-iron engine beams were unheard of.

"The Lowmoor Iron Company exhibit bowl-shaped vessels, drawn out by the hammer from circular iron plates, from 3 feet to 3 feet 10 inch. in diameter, and perhaps ⅜ inch thick. These are placed upon a table, the top of which is a large plate of iron, supported by legs of round iron bars, each tied in a knot.

"The Bowling Iron Company, the Monkbridge, the Shelton Bar Iron Company, and others, exhibit samples of their productions, the Shelton Company sending a plate of 112 square feet area, and $\frac{9}{16}$ inch thick.

"The Weardale Iron Company, of Tow Law, Durham, send a variety of engine axles, tyres, &c., of Bessemer steel.

"Messrs. Taylor Brothers, of Leeds, send cranks, tyres, &c.

"The Mersey Iron and Steel Company, of Liverpool, exhibit a double-throw wrought-iron crank-shaft, weighing between 24 and 25 tons, and made for Messrs. Penn & Sons, for the engines of one of the new iron-plated frigates of 1,350 horse-power. The forging is a very smooth one, and a notification appears on one of the cranks that it has neither been smithed nor tooled.

"The greatest display of steel in the Exhibition, and no doubt the greatest ever made, is that of Herr Krupp's, in the western annexe. The whole quantity of cast-steel exhibited by this maker must be about 100 tons, covering a platform 40 feet long and 17 feet wide. On another page we have given a view of the collection as it stands. There are two halves of an ingot, which, before breaking in two, weighed 21 tons. The ingot is 3 feet 8 inch. in diameter, and each half is nearly 5 feet long. After it was cast it was cut around in the middle, and broken under Krupp's famous hammer, the head of which weighs 40 tons and falls 10 feet. The fracture shows perfectly sound metal, although the ingot has never been hammered. Another ingot, 8 feet long, and weighing about 8 tons, is shown, rough at one end and hammered down at the other. An ingot, originally weighing nearly 15 tons, and 30 inch. by 17 inch. in section, is shown broken into four pieces, so as to disclose the internal character of the metal. A cast-steel intermediate shaft, of the kind supplied to the Holyhead and Kingston boats, is also shown. It is about 15 feet long and 2 feet in diameter, with a large air-pump crank-throw in the middle. The weight of this specimen is 15¼ tons. A cast-steel breech-loading gun, weighing 9 tons, and having a bore of 9 inch., is exhibited, bored and partly turned. Also guns of the like description, and in like condition, rating, respectively, as 100, 68, 40, 25, and 12-pounders; also a rifled muzzle-loading 4 pounder. Six small steel cylinders are also shown, to illustrate different systems of rifling. A cast-steel double-crank screw-shaft, 24 feet long and 16 inch. in diameter, made for the 700 horse engines of the North German Lloyd's steamers, running from Bremen, *viâ* Southampton, to New York, is shown, and also a finished steel shaft for one of the Danube steam-boats. A steel pump rod, 30 feet long and 5 inch. in diameter, is shown, and but for limited space a rod 60 feet long would have been shown, up to which length they have actually been made. A cast-steel two-bladed screw propeller, 9 feet in diameter,.and weighing 800 lbs., is shown; also the head and flukes of an anchor on Trotman's principle. A number of cast-steel engine tyres are exhibited, among them a pair on the wheels, as taken from the Eastern Counties Railway, after running 67,000 miles without once turning, the wear being very uniform, and about ¼ inch in depth all round. A number of cast-steel axles, one having been run 66,179 miles, and another which has run 73,494 miles, are also shown. There is also a collection of steel rifle barrels, specimens of tool steel, rolls, &c. But for the limits of the space allotted to him, Herr Krupp would have exhibited some large steel plates. He is now erecting a rolling mill with 2,000 horse-power, and rolls 15 feet in clear length between the standards, for rolling armour and other plates of cast-steel. By this mill he will be enabled also to turn out plates each sufficiently large for the whole barrel of the largest locomotive boiler ever made. The Peninsular and Oriental Steam Navigation Company, we may add, have commenced the use of Krupp's steel shafts in their steamers. We should observe, while we are upon this subject, that in the most important cases the examples of Krupp's steel in the Exhibition have been purposely broken, to show the quality of the metal. The fractures show sound steel over their whole surface, and afford far better evidence of quality than any mere forging, however large, or however handsomely finished.

"The Bochum Company, whose works are also in Rhenish Prussia, and but a few miles from Krupp's, exhibit a cast-steel bell, weighing between 8 and 9 tons, as also a pair of cast-steel engine tyres of the great diameter of 9 feet 6 inch., besides cast-steel wheels and axles for railway carriages, &c.

"The mode of casting steel into bells, wheels, and other objects, originally practised at Bochum, has for some time been adopted in Sheffield, and Messrs. Naylor, Vikers, & Co. exhibit a number of such castings. Considering the difficulties in casting steel, these examples, although showing numerous small surface cavities, are, nevertheless, very creditable to the makers.

"Messrs. Charles Cammell, of the Cyclops Steel Works, Sheffield, send numerous examples of their productions, and also a large and handsomely finished machine, made by Messrs. Greenwood & Batley, of Leeds, for testing Messrs. Cammell's steel daily, at their works, by tension, compression, and torsion. We expect to be able shortly to give an illustration of this machine, and shall defer till then a notice of the manufactures accompanying it.

"Messrs. Shortridge, Howell, & Co. contribute an interesting collection of 'homogeneous metal,' and other steel or steely iron plates, tubes, ingots, &c. A cast-steel ingot, 10 inch. square, presents a splendid fracture, and is accompanied by a case of numerous smaller samples of steel showing fractures also. A plate of 'homogeneous metal' 6 feet 6 inch. long, 6 feet wide, and $\frac{9}{16}$ inch thick, is exhibited, along with one 16 feet 6 inch. long, 3 feet wide, and $\frac{1}{4}$ inch thick. There is also a length of lap-welded tube of the same material, 3 feet in diameter and $\frac{3}{16}$ inch thick. Homogeneous metal, so called, has only been produced to any extent since 1856. Wrought-iron, as is well known, is almost, if not entirely, infusible, but when cut into scrap and put in a crucible along with 5 oz. or 6 oz. of charcoal to every 40 lbs. of metal, it will melt under a high heat, and become exceedingly tough and strong. The ordeal is a severe one, however, for the melting pots, and 'homogeneous' metal thus produced is never likely to be cheap. Its strength is undoubtedly great, and its quality excellent. Sir John Burgoyne, we understand, in reporting upon some rifle experiments conducted at Chatham, stated that a $\frac{3}{16}$-inch plate of this metal was proof against a Minié ball at 100 yards range, whereas a $\frac{1}{2}$-inch plate of Lowmoor iron was not so. The force required to perforate a plate by a rifle bullet must be the same as that required to make a like hole by a punching machine; and as the resistance to punching is exactly as the tensile strength, we should say the alleged results of the Chatham experiments were perfectly probable, Messrs. Napier's experiments having shown the greatest cohesive strength of small bars of Lowmoor iron to be 67,876 lbs. per square inch, while that of Messrs. Shortridge, Howell, & Co.'s homogeneous metal was 99,570 lbs., the lowest breaking strain being 82,218 lbs. Mr. Howell also exhibits some cast-steel shells, cast without a core, the metal having been poured into a mould made to revolve rapidly in two directions at the same time. Shells can be thus cast of any thickness, and when afterwards filled in action with molten iron, the heat, instead of melting them, will only increase their toughness. On this account Mr. Howell hopes to be able to fire these shells red hot through thick armour-plates.

"We must close for the present with a notice of the objects, in Bessemer steel, exhibited in the case of Messrs. Bessemer & Co., of Sheffield. This case, apart from its contents, we may observe, is one of the handsomest objects in the building, occupying a space of 35 feet square in the southern portion of the eastern transept, near the dome. The simple discovery which has given to the world the cheap and ready means of making this steel direct from pig-iron is, perhaps, the most remarkable addition to modern scientific knowledge since the invention of the steam engine itself. The wide interest attaching to the process justifies us in describing it, with proper illustrations, on another page.

"Messrs. Bessemer & Co. exhibit the following objects in Bessemer steel:—1st. Cast-steel octagon ingot, 14 inch. diameter, broken to show that it is perfectly solid; the fracture is preserved at one end, while the other is turned up in the lathe, and its perfect surface can only be detected from forged steel by the unturned portion still exhibiting the marks of the mould. As an ingot it is a most perfect example, and is the best answer to the statements of 'W. S. P.' in a letter which appeared in our last number. 2nd. A cast-steel ingot, 18 inch. square, weighing 28 cwt.; this ingot is the 6,410th 'direct steel' ingot made by Messrs. Bessemer & Co., of Sheffield. 3rd. A 24-pounder steel gun, in the rough, with the trunnions formed upon it, out of an ingot of the same size as the above. This gun is the ninety-second made by Messrs. Bessemer & Co. 4th. A 24-pounder steel gun, bored and finished by Messrs. Fawcett, Preston, & Co., of Liverpool, for whom a dozen of the same size are in course of being forged. 5th. A 34-pounder spherical shot in steel; also a 43-pounder spherical shot, with a flat zone, fitting accurately the bore of a 32-pounder, and an elongated 80-pounder for the same gun. The latter, being on the turbine principle, is suitable for discharging from a 'smooth bore,' and will receive rotatory motion during its passage along the chase of the gun, thus rendering rifling unnecessary, and giving a higher velocity to the projectile. 6th. There are also half-a-dozen swords, a shield, a dozen bayonets, cuirass, helmet, Enfield rifle, and rifle barrels and revolver, all made of Bessemer steel, by Mr. Reeves, of Birmingham. In the engineering department will be found a 50 horse-power crank-shaft, made by Messrs. Galloway, of Manchester; a marine engine cross-head, by Fawcett, Preston, & Co., of Liverpool; an immense screw nut, and screw and box for a rolling mill, by Messrs. Hawkes & Smith, of Birmingham; a steel piston rod, 7 inch. diameter and 14 feet long, two smaller ones, and the piston rod of a locomotive engine, finished bright, and then folded backward and forward into a short length by the steam hammer, the severe blows of which are shown on its surface. There is also a hydraulic press cylinder and 7-inch ram fitted into it, by Messrs. Peel, Williams, & Peel, of Manchester, who have a patent for steel cylinders. The extreme lightness of this press renders it particularly applicable for cotton pressing in India. This thin cylinder is capable of sustaining a pressure of 12 tons on every square inch. In railway matters we have—first, a rail 40 feet in length, rolled at Crewe. It is a beautiful sample of its kind. Some hundred tons of the rails are now laid. Next is a rail twisted cold into a spiral like a ribbon, and it does not show a single flaw after this severe treatment. All idea of the 'brittleness of steel' vanishes with the inspection of this example. There are also some close bends of rails, one of which is deserving special notice. Mr. Ramsbottom, the able engineer of the railway works at Crewe, had this piece taken up while covered with sharp frost, and placed under the large steam hammer, where it stood the blows necessary to double both ends together, without showing the smallest indication of fracture. This is an important fact in relation to the action of frost on steel, which is not affected thereby like iron. Under a glass shade is also exhibited several crop ends, or waste pieces, cut from rails now in use on the London and North-Western Railway. They show beautiful fractures. Some of the pieces have been polished at the ends, to show how perfectly free they are from flaws; one specimen, being polished all over, gives an excellent idea of the very beautiful material which lies below the dark scale of these homogeneous rails. There are also a pair of locomotive engine tyres and a passenger carriage tyre, one left black from the rolls, and the other two finished bright. These tyres are especially interesting from the fact that the first solid form that the metal assumed was that of a hoop with a raised flange; the metal was never even in the form of pig-iron, having been run direct from the blast furnace into one of Bessemer's converters, and, after nine minutes' blowing, was run into the mould, and formed into a *cast-steel tyre.* In these beautiful tyres we have an example of the complete and precise working out of Mr. Bessemer's first plans, as laid down in 1856 in his paper at Cheltenham. The metal was run at once from the blast furnace into an upright fixed cylindrical vessel, with horizontal tuyeres fixed radially around the lower part, the quality or temper of the steel being ascertained by the appearance of the flame and sparks, and the metal was tapped by a bar, as practised in iron-founding, and as indicated in Mr. Bessemer's patent. There is no alloy of metal, no 'spiegel eisen,' *and no manganese* in any form whatever, nor was any metal employed to re-carbonize, the entire process being precisely the same in all its details as that described to the meeting at Cheltenham, and patented by Mr. Bessemer. There are also some extraordinary examples of the toughness of the Bessemer steel, made from British coke pig-iron, among which may be enumerated two deep vessels of 1 foot in diameter, with flattened bottoms and vertical sides. At the top edge one of them is $\frac{5}{8}$ inch, and the other $\frac{7}{8}$ inch in thickness. These were forced up in a press from flat circular disks of steel. They can now be drawn into long tubes, either of their present diameter, or they may be reduced to locomotive boiler tubes of 2 inch. diameter. There is also shown an attempt to raise a piece of the best quality of Staffordshire iron plate by the same tools; this only went about as deep in proportion as a dinner plate before it fractured all around the punch, and almost fell in two pieces. It may be remarked that Mr. Parkes, who invented this beautiful system of making unwelded tubes, has been obliged to use the very highest quality of copper for that purpose, as the ordinary copper of commerce generally cracks; but the Bessemer steel, as seen by these examples, stands this fearful ordeal with perfect safety. There is also a 5-inch square bar folded up quite close (red-hot), as an example of the powers of stretching hot without a symptom of crack or flaw. Another 5-inch bar is half cut through, and then doubled close up, without any sign of fracture; a mass of 4 inch. in thickness is cut into nine cubes, not quite separated, and showing great tenacity as well as facility in working the metal. A 4-inch square bar has been so twisted while hot that its angles have approached within less than half-an-inch of each other, so that what was originally 1 foot length of surface has now become 26 feet, while the central portion of the bar still preserves its original length of 1 foot. Mr. Bessemer also exhibits beautiful samples of steel wire, by

Fox, of Deepcar, near Sheffield; wire cards for cotton and wool, by Messrs. Fairbairn Brothers; and some of these sharp elastic cards may be seen in the western annexe on the carding machines of Messrs. Platt Brothers. There are also samples of plates of 4½-inch. to $\frac{1}{64}$ inch thick; also round and square bars from 4 inch. diameter to ¼ inch; also flat and octagon tool steel. Among the tools exhibited are some beautiful taps, from ¼ inch to 3 inch. diameter, by Chatwin, of Birmingham; files, saws, and a variety of other tools, by Ibbotson, of Sheffield; steel pens and split rings, by Mason, of Birmingham; and some beautiful cutlery, by Mr. Rotherham, of Sheffield. There are also exhibited on boards two piles of 'scrap'—one is boiler-plate scrap, and the other 'ladle skulls,' that is, the thin shell of steel which sets in the ladle during the casting process. It is, consequently, neither hammered nor rolled. These piles have placed before each of them a bar of steel, made by treating a similar pile precisely the same as scrap-iron would be treated, and forging them into a solid bloom. A part of each bar, or bloom, has been turned in the lathe to show how sound the welding of some hundreds of pieces may be made.

"Whatever may be the contrasts between the former and the present International Exhibitions, there is none in which the superiority of the present is more manifest than in the examples of iron and steel already noticed in this article. In 1851 the Butterley Company could have sent no such beams and plates, the success of the great Mersey forging would have been to some extent doubtful, while as for Krupp's great steel forgings, they would have been looked upon as impossible, and Bessemer's steel, the Bochum steel castings, and Messrs. Shortridge & Howell's 'homogeneous metal' were unknown. With such progress in so brief a period, what may we not look for in the future?"

M.

EXTRACT FROM "PROCEEDINGS OF THE SCOTTISH SHIPBUILDERS' ASSOCIATION," *5th January*, 1863.

"J. G. LAWRIE, Esq., *Vice-President, in the Chair.*

"AMONGST the preliminary business, Mr. Mansel alluded to an article which had appeared in a recent impression of the *Army and Navy Gazette*, in reference to which (in concurrence with the opinion of several members; and as a simple act of justice to Mr. David Kirkaldy) he had considered it his duty to write to the Editor of that periodical the following letter:—

"SCOTTISH SHIPBUILDERS' ASSOCIATION,
"QUEEN'S ROOMS, GLASGOW, *24th Dec*, 1862.

"*The Editor of the Army and Navy Gazette.*

"SIR,—I have noticed an article in your impression of the 13th December, describing a highly important improvement in the mode of treating steel, which had been lately introduced at Woolwich Arsenal.

By the simple process of heating steel, and then plunging it in oil, or, as we may say, by hardening it in that medium, it is correctly stated that the tenacity of the metal is greatly increased; and there is little doubt but the inferences arrived at will be fully verified, and we will find 'this toughened metal is likely to form a suitable material for forming the interior tubes of built up guns,' and again, that 'the virtually condemned steel vent-pieces, which cost several thousands of pounds, can now be brought into use.'

"Exceptions, however, are likely to be taken to Mr. John Anderson, Assistant Superintendent* of Woolwich Arsenal, being 'congratulated on his valuable discovery,' seeing that, about two years previously, the fact upon which it was based was openly published as one result of the careful and elaborate set of experiments made for Messrs. R. Napier & Sons, of Glasgow, by Mr. David Kirkaldy.

"These experiments formed the subject of a paper by Mr. David Kirkaldy, entitled, 'Results of an Experimental Inquiry into the comparative Tensile Strength and other Properties of Steel and Wrought-Iron under various conditions,' which was read before the Scottish Shipbuilders' Association on 1st April, 1861; an abstract of the conclusions arrived at appearing about that date in several periodicals, for example, *Glasgow Herald*, 4th April, 1861, *Engineer*, 12th April, 1861.

"'*Conclusion 11th.*—Influence of various kinds of treatment. Thus, in the hardening of steel: by hardening in water, in the ordinary way, the strength was found to be reduced twenty-six per cent.; whereas, by hardening in oil, the strength was increased seventy-nine per cent.'

"The process of tempering in oil has, I believe, been long known and practised, in order to confer desirable qualities on steel instruments; but, so far as I am aware, Mr. Kirkaldy was the first to definitely point out the vast increase of tenacity of oil-hardened steel over the same steel when water-hardened. In conclusion, I may mention that the experiments referred to, together with a prior set communicated to the 'Institution of Engineers in Scotland,' are embodied in Mr. Kirkaldy's volume of experimental data, published last July.—I have the honour to remain, yours truly,

"ROBERT MANSEL, *Secy.*

"Mr. Mansel was not aware of any special notice having been taken of this communication; but subsequently, in an editorial note, the claim of novelty, advanced for Mr. Anderson, had been withdrawn.

"MR. BRAGGE.†—A great deal of amusement was excited in Sheffield by the appearance of this article, claiming as an original invention a process which had been known in Sheffield for a century at least. It is a well-known fact—every one who has had practical experience of large screw taps knows—that when these taps are hardened in water, the very first time of using carries off the cutting edge; when they are hardened in oil they will stand for a very long time.

"The CHAIRMAN said—It is quite correct what Mr. Bragge tells us, that the tempering of large taps in oil makes them stand a great deal better. I am not sure, however, although that is the case, that there was any clear idea that the bar of steel, per square inch, would stand a greater breaking strain. It may have been so; but I am not aware that that was clearly brought out.

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* Since appointed Chief Superintendent.

† Of Messrs. J. Brown & Co., Atlas Works, Sheffield.

"Mr. Bragge.—It gave it a quality of toughness which, when tempered in water, it had not. When tempered in water brittleness is the inevitable result; when tempered in oil that brittleness is absent.

"Chairman.—That toughness applies, not only to the surface, but to the interior of the bar?

"Mr. Bragge.—Yes. It appears to me you cannot have two qualities—an external and an internal quality of hardness—unless in a very large mass.

"Chairman.—Suppose you were to temper a bar two inches square in water, and another in oil—cut a bar of one square inch from the centre—would that tempered in oil be stronger? Was it known before Mr. Kirkaldy pointed it out that the one tempered in oil would be stronger?

"Mr. Bragge.—I am not aware that the experiment has been made. But the simple fact of hardening in oil to obtain toughness, has been known since saws were made; for saws have always been, within the memory of man, hardened in oil, and never in water.

"Mr. Kirkaldy.—If you harden a saw in water it will be all bent and twisted; and it was only to prevent this *twisting* that oil was used instead of water.

"Mr. Bragge.—There seems to be something in the giving off of the heat in the water which oil does not possess. The water absorbs, as it were, the heat of the steel instantaneously, while the oil absorbs it with a certain degree of slowness; and, therefore, in hardening springs of the best quality, oil is adopted instead of water.

"Mr. Kirkaldy.—I think it could not have been known previous to my experiments that the *strength* of steel was so greatly increased by being hardened in oil; otherwise, why were 'the steel vent-pieces' referred to by the Editor of the *Army and Navy Gazette*, on 13th December, not originally so treated? I may mention that Mr. Anderson obtained a copy of my *Experiments on Wrought Iron and Steel* from myself on the 20th October; and probably his attention was directed to the subject from the facts elicited in course of my experimental inquiry.

"Mr. Barber.—I think it is quite right that credit should be given to whom credit is due; and I think Mr. Mansel did quite right to let the public know that Mr. Kirkaldy had found out the fact before Mr. Anderson."

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"L'emploi du fer et de l'acier devient de plus en plus général. On applique aujourd'hui ces métaux à la construction des maisons, des ponts, des navires, là où le bois et la pierre étaient seuls employés il y a vingt ans. Dans ces diverses applications, la connaissance des propriétés du métal est de la première importance. Elle intéresse non-seulement les résultats économiques des constructions, mais elle intéresse aussi la sécurité des ouvrages. Une explosion de chaudière à vapeur, une rupture d'essieu de chemin de fer, la chute d'une charpente ou d'un pont, le naufrage d'un navire, n'ont souvent d'autre cause qu'une erreur commise à la construction dans l'appréciation des qualités des métaux employés. Il semblerait donc qu'une question qui intéresse aussi directement la vie des hommes eût dû attirer depuis longtemps déjà l'attention des expérimentateurs. Il est malheureusement aisé de reconnaître qu'il n'en a pas été ainsi. Nous ne possédons en effet aujourd'hui que quelques données éparses et tout à fait insuffisantes sur la résistance du fer. Nous n'en avons presque aucune sur la résistance de l'acier. . . . L'ouvrage que M. Kirkaldy a publié à Glasgow à la fin de l'année dernière, vient nous offrir le seul moyen possible, nous ne dirons pas de trancher toutes ces questions, mais tout au moins d'en entreprendre l'étude avec quelque chance de succès en nous offrant un ensemble considérable de faits. . . . Tels sont les points principaux sur lesquels le précieux travail de M. Kirkaldy vient éclairer l'industrie. Mais il est bien d'autres questions encore pour lesquelles on pourra utilement chercher les éléments d'une solution dans un recueil aussi étendu d'expériences, et nous ne pouvons mieux faire, en terminant ce compte-rendu déjà surchargé peut-être, que d'engager tous ceux qui ont intérêt à bien connaître les propriétés du fer et de l'acier à lire attentivement l'ouvrage de M. Kirkaldy."

Extrait des Mémoires de la Société des Ingénieurs Civils.

Comparaison des Propriétés Résistantes du Fer et de l'Acier. Par A. Brüll, Ingénieur Civil.

"J'ai eu la bonne fortune de lire un ouvrage anglais qui a paru récemment, et qui renferme les résultats des épreuves à la traction faites à Glasgow, par M. Kirkaldy, sur plus de 1,500 échantillons de fer et d'acier de toute espèce. . . . Les expériences de M. Kirkaldy montrent donc aussi qu'il est inexact de dire d'une façon générale que l'acier est plus cassant que le fer. Oui, il y a des aciers plus cassants que certains fers, et tout le monde sera d'avis, avec M. Tresca, de réserver ces aciers-là aux emplois qui exigent un métal d'une grande dureté; mais il y a aussi des aciers ductiles et plus ductiles que ne le sont la plupart des fers, et qui allient à cette grande ductilité une résistance bien supérieure. Pour ces aciers-là, nous pouvons hardiment retirer la restriction que nous avons dû admettre tout à l'heure. . . . Il résulte d'une série fort intéressante d'expériences faites par M. Kirkaldy et rapportées dans son ouvrage, que la charge limite d'épreuve d'une barre qu'on entaille n'est pas abaissée tout à fait proportionnellement à la diminution de section qu'amène l'entaille, de sorte que les raisonnements qui précèdent sont, au point de vue numérique, seulement approximatifs. . . . Mais comment s'y prend l'ingénieur pour profiter le plus avantageusement de cette diversité? Il étudie les propriétés des matières qu'il doit employer, il se familiarise avec leur variation, il apprend à mettre en regard de chaque application la provenance et le mode de fabrication qui y conviennent le mieux. Il nous reste à faire, ou du moins à parfaire, cette sorte d'éducation à l'égard de l'acier qui est une matière relativement nouvelle, et je pense que le moyen d'arriver à un succès qui paraît certain, c'est non pas de se laisser effrayer dès l'abord par quelques difficultés d'emploi, mais bien de chercher à nous instruire par l'expérience pratique de tout ce qui intéresse les diverses variétés d'acier et les emplois auxquels elles conviennent."

PLATE II

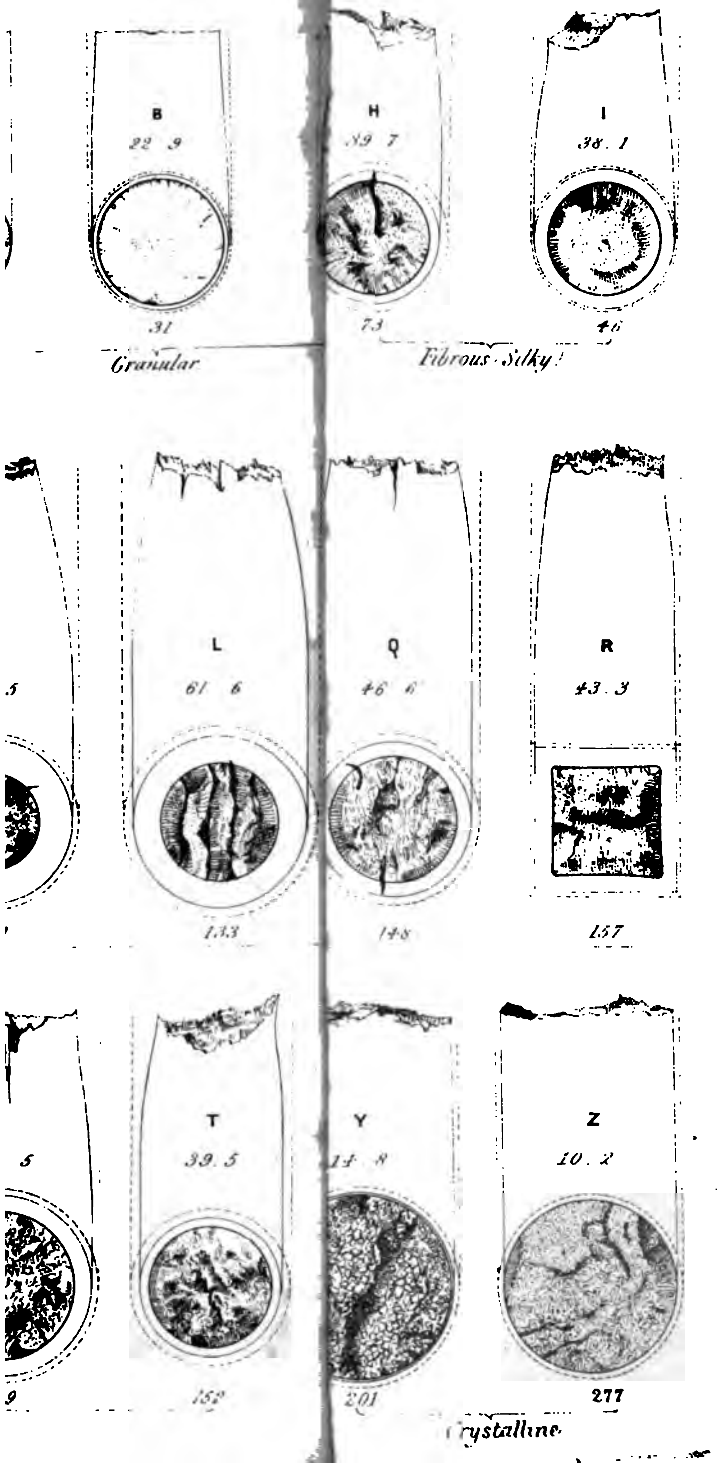
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PLATE III.

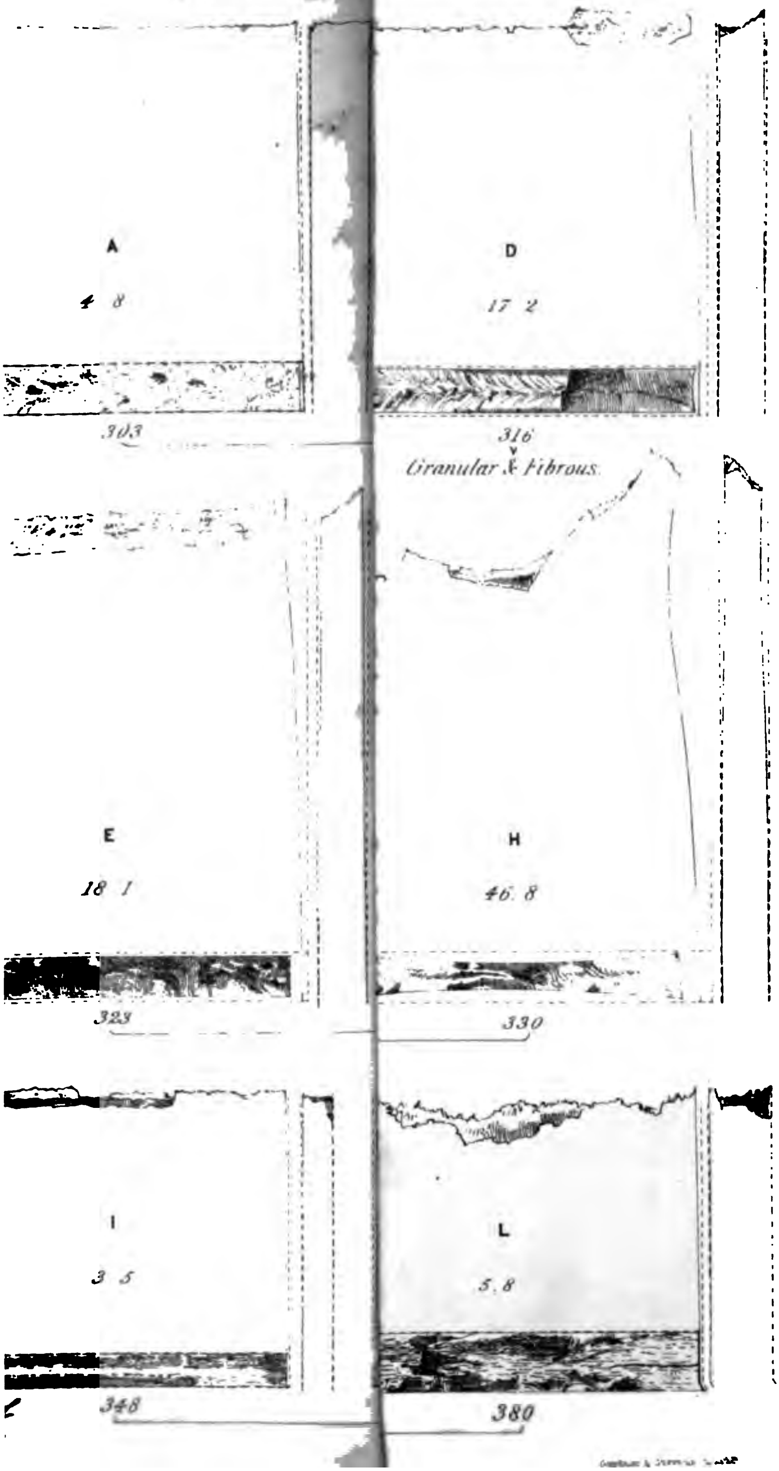
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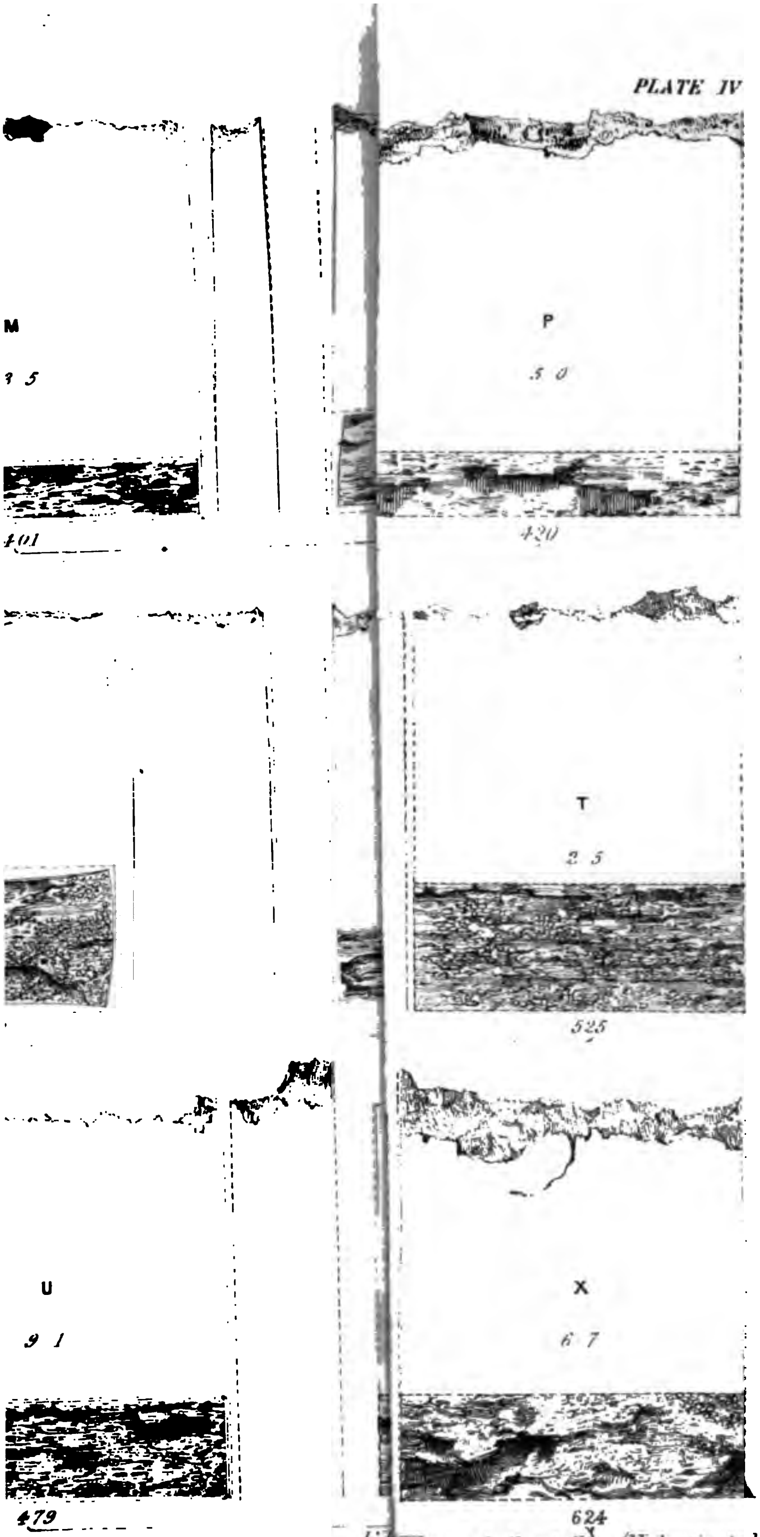
PLATE IV



Fibrous & Crystalline (Unlaminated)

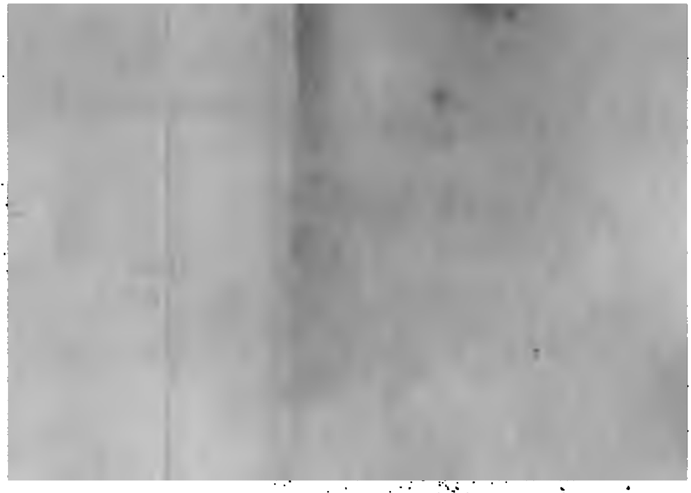


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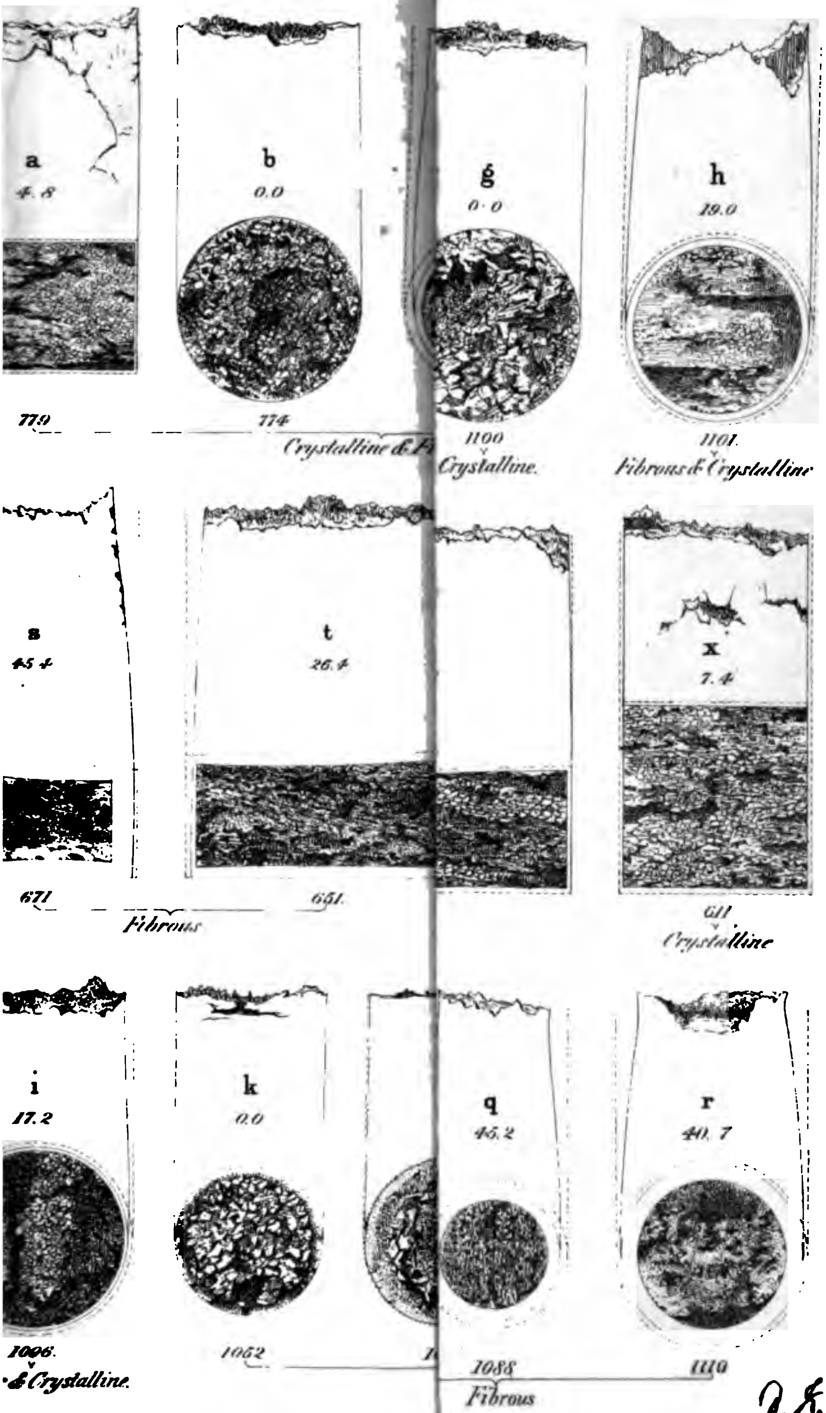
PLATE V.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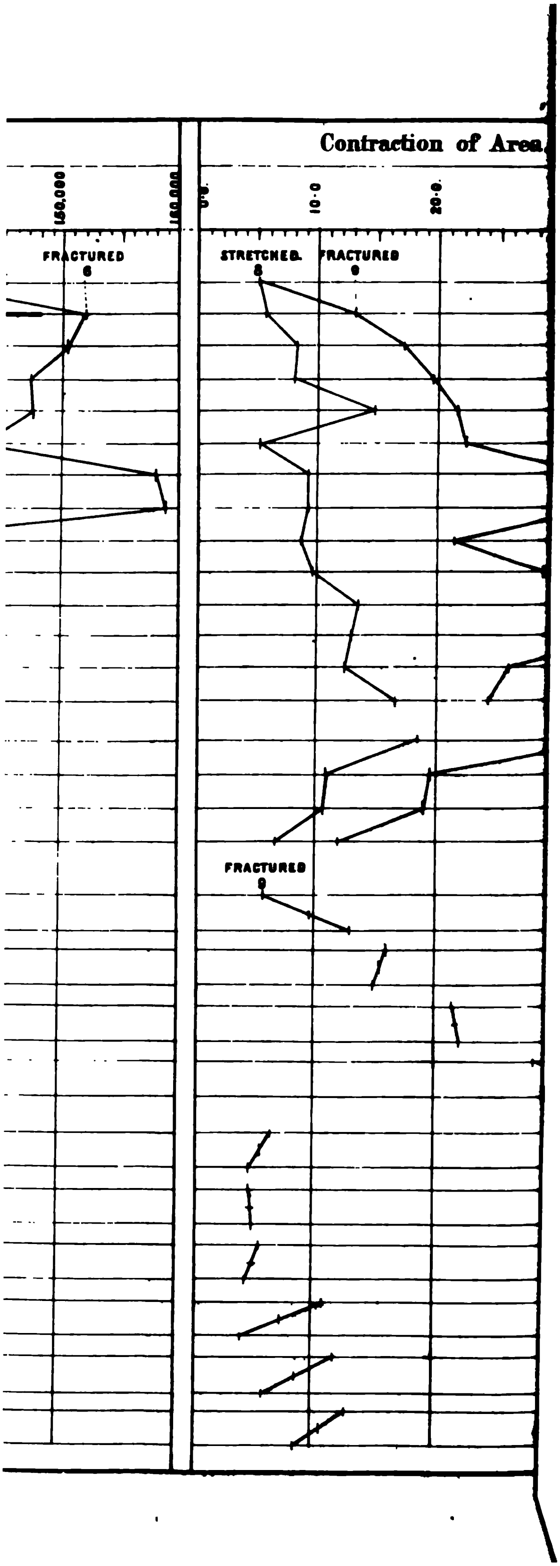
J.K.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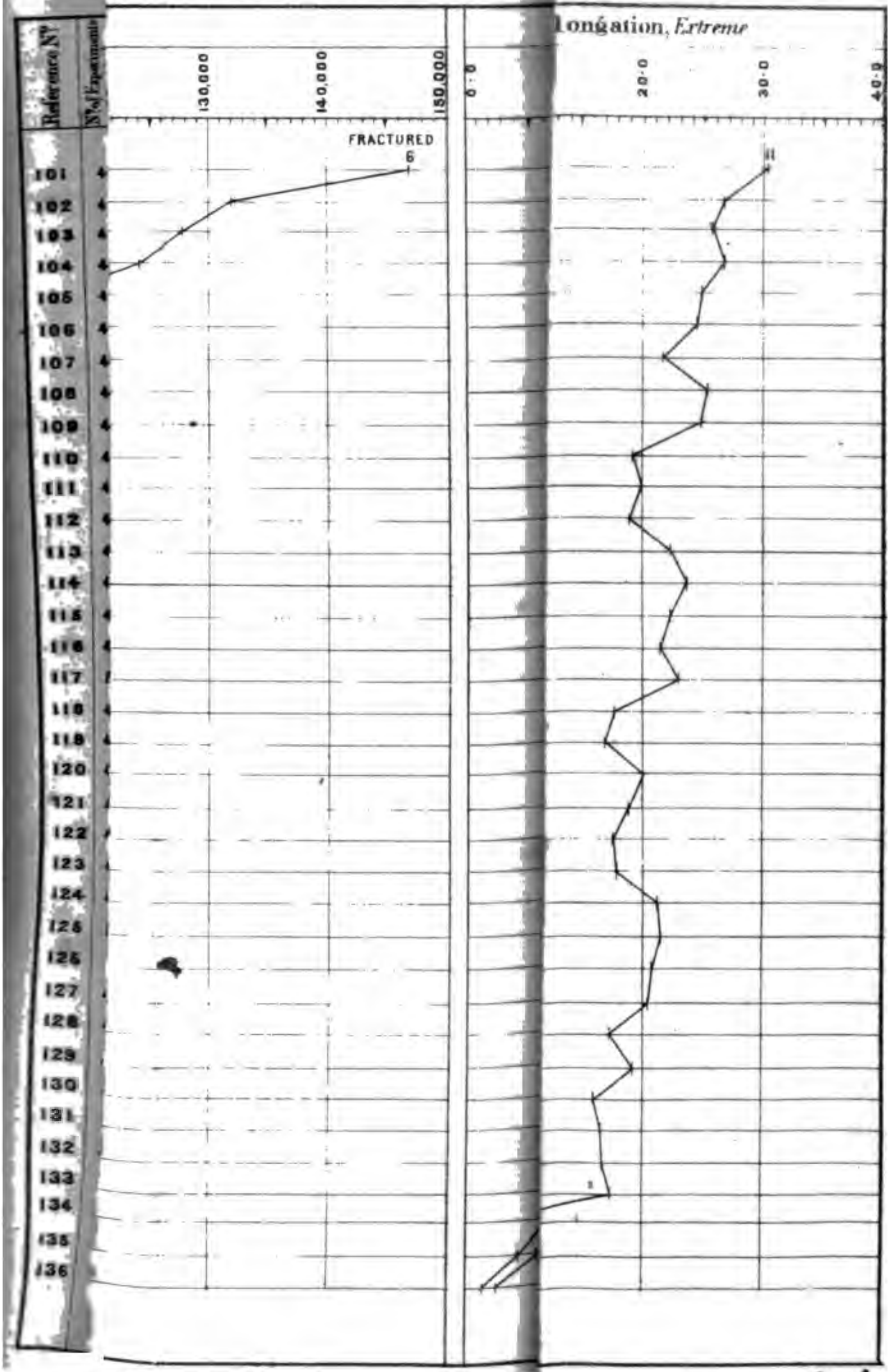
9

NGTH OF STEEL & WROUGHT IRON

PLATE VI

TABLE G.

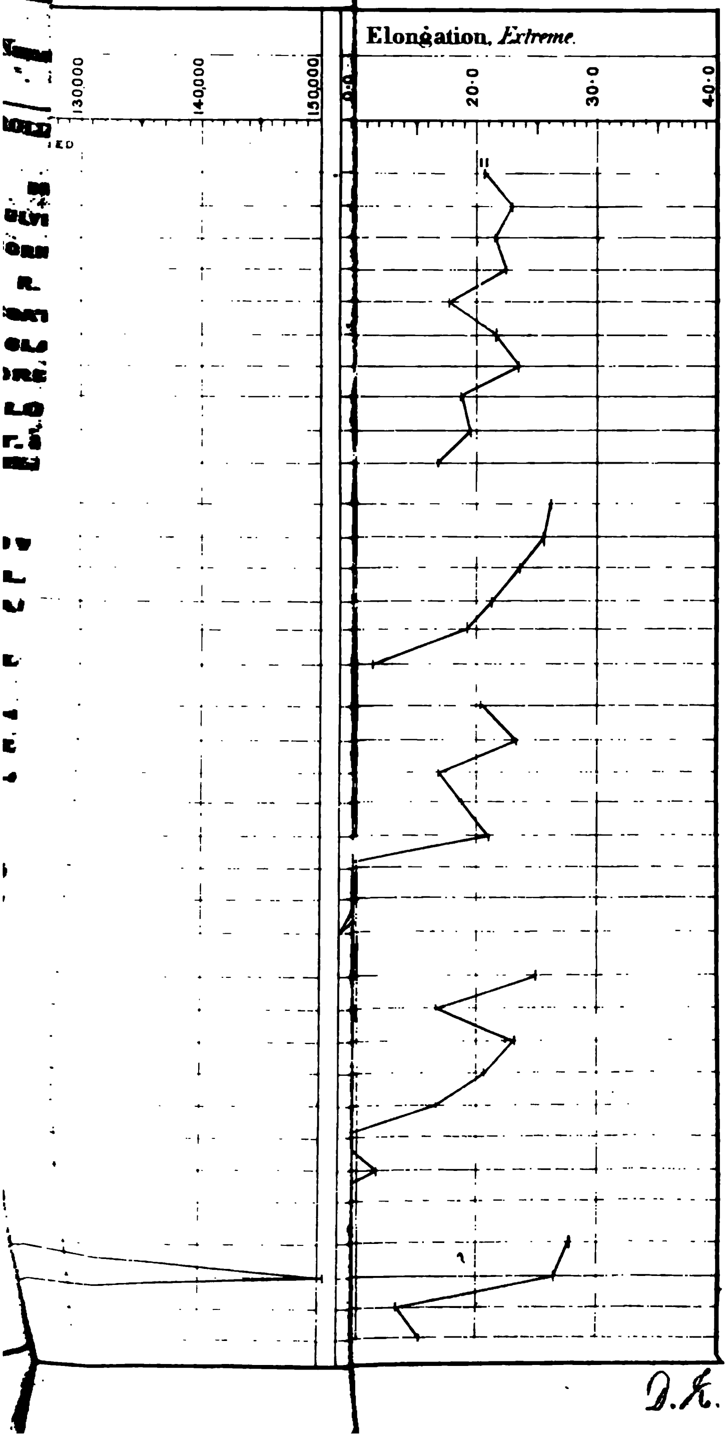


B.A.

H OF STEEL & WROUGHT IRON

ABLE G.

PLATE VIII



D.K.

PLATE IX

No. of experiments on each.	Names of the Makers or Works	Length, Cross
4 4	FARNLEY.	L C
3 6	FARNLEY.	L C
6 5	LOWMOOR.	L C
4 4	FARNLEY.	L C
5 5	BOWLING.	L C
6 6	◈ GOVAN. ◈	L C
3 3	BRADLEY & Cº S C	L C
6 6	BRADLEY & Cº L F.	L C
3 3	BRADLEY & Cº	L C
2 2	MALINSLEE BEST	L C
3 4	CONSETT, BEST. BEST.	L C
10 10	Dº Dº	L C
24 24	Dº Dº	L C
3 2	THORNEYCROFT. BEST BEST.	L C
5 5	SNEDSHILL BEST	L C
6 6	WELLS BEST BEST	L C
6 6	GLASGOW BEST BOILER	L C
18 14	GLASGOW BEST BEST.	L C
7 7	WELLS BEST BEST	L C
6 6	MAKER'S STAMP UNCERTAIN.	L C
3 3	K. B. M.	L C
5 5	LLOYDS, FOSTER & Cº BEST.	L C
11 11	GLASGOW BEST BEST.	L C
6 6	GLASGOW SHIP.	L C
3 3	MOSSEND BEST BEST.	L C
6 6	GOVAN BEST.	L C

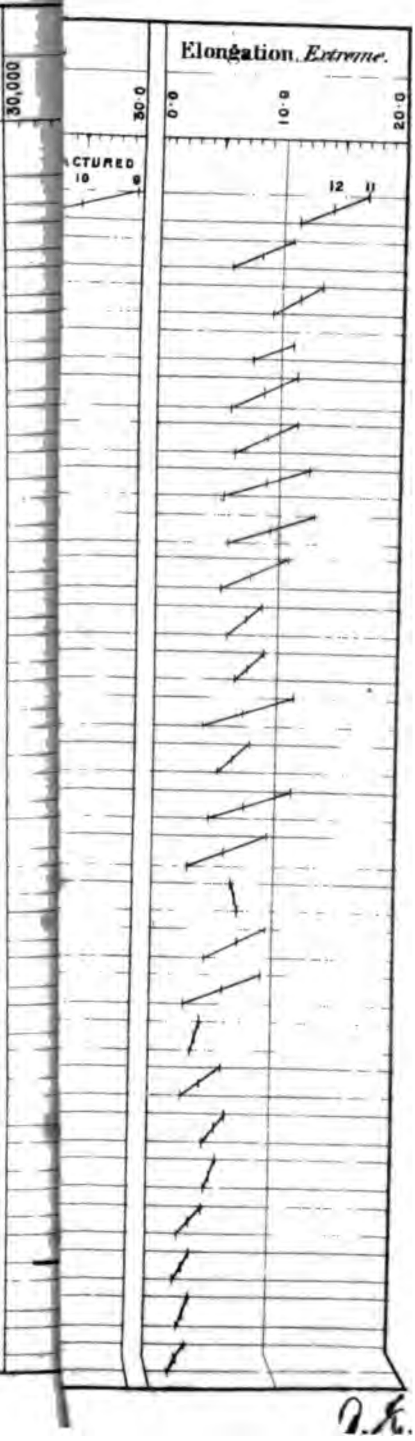
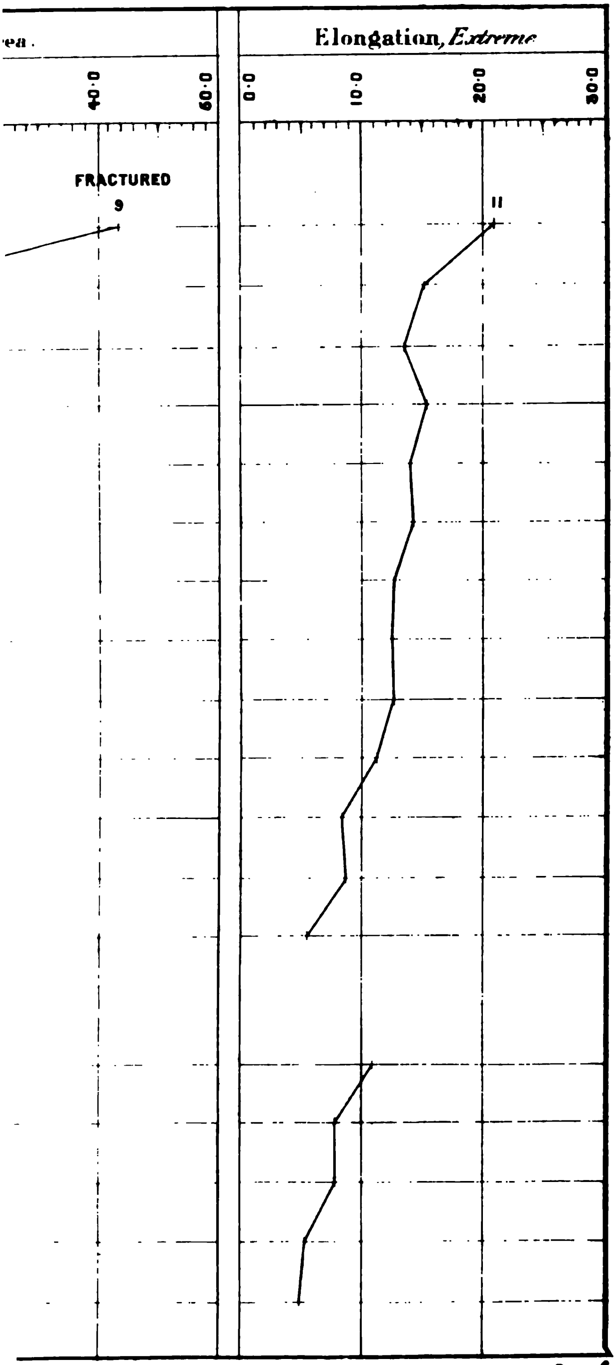
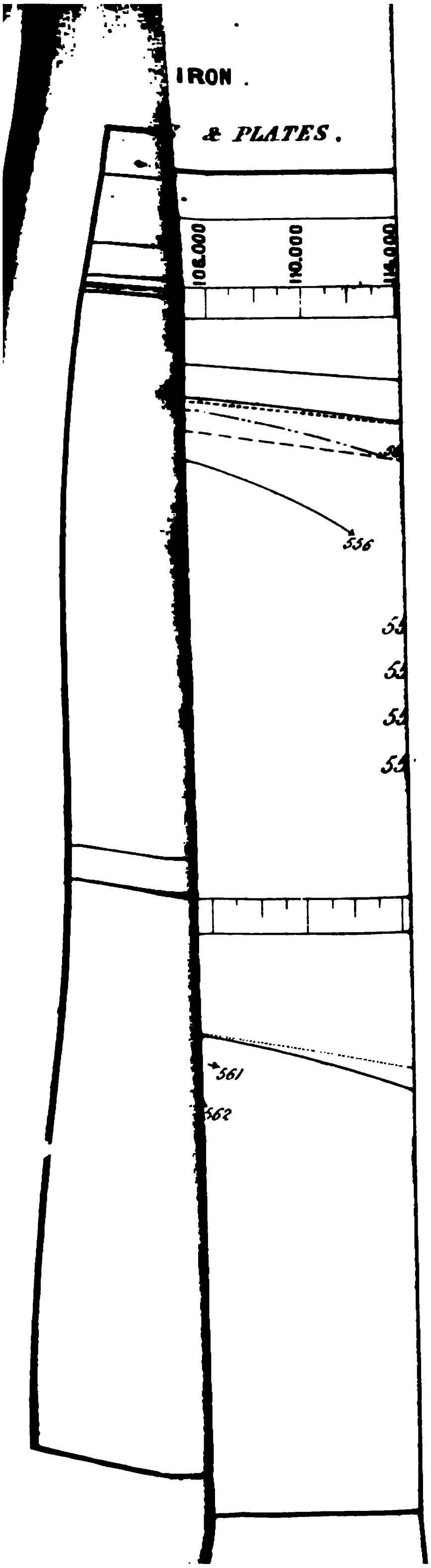


PLATE X





IRON .
& PLATES .
108,000
110,000
556
561
562

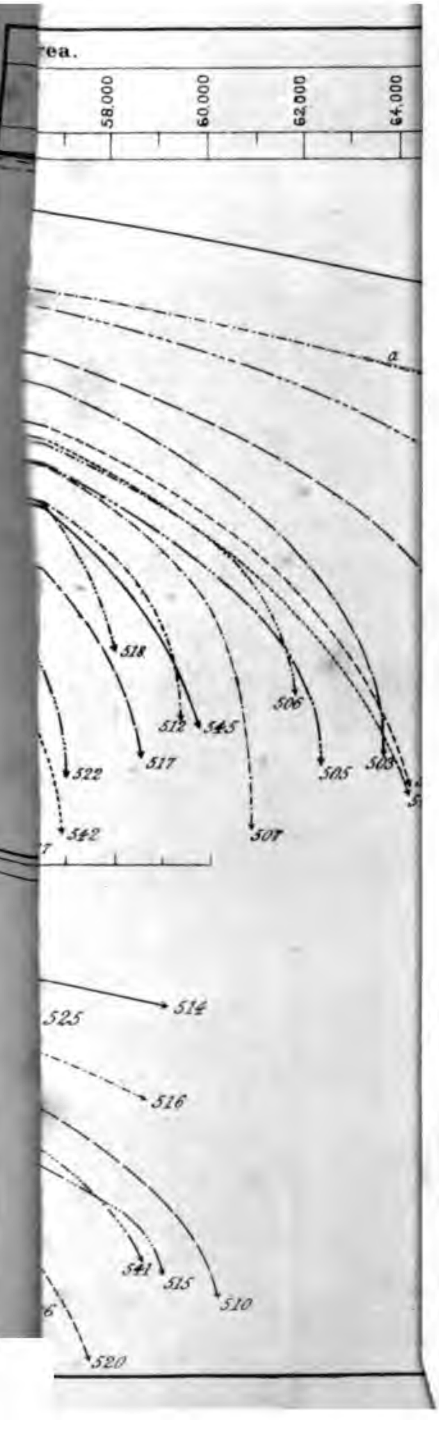
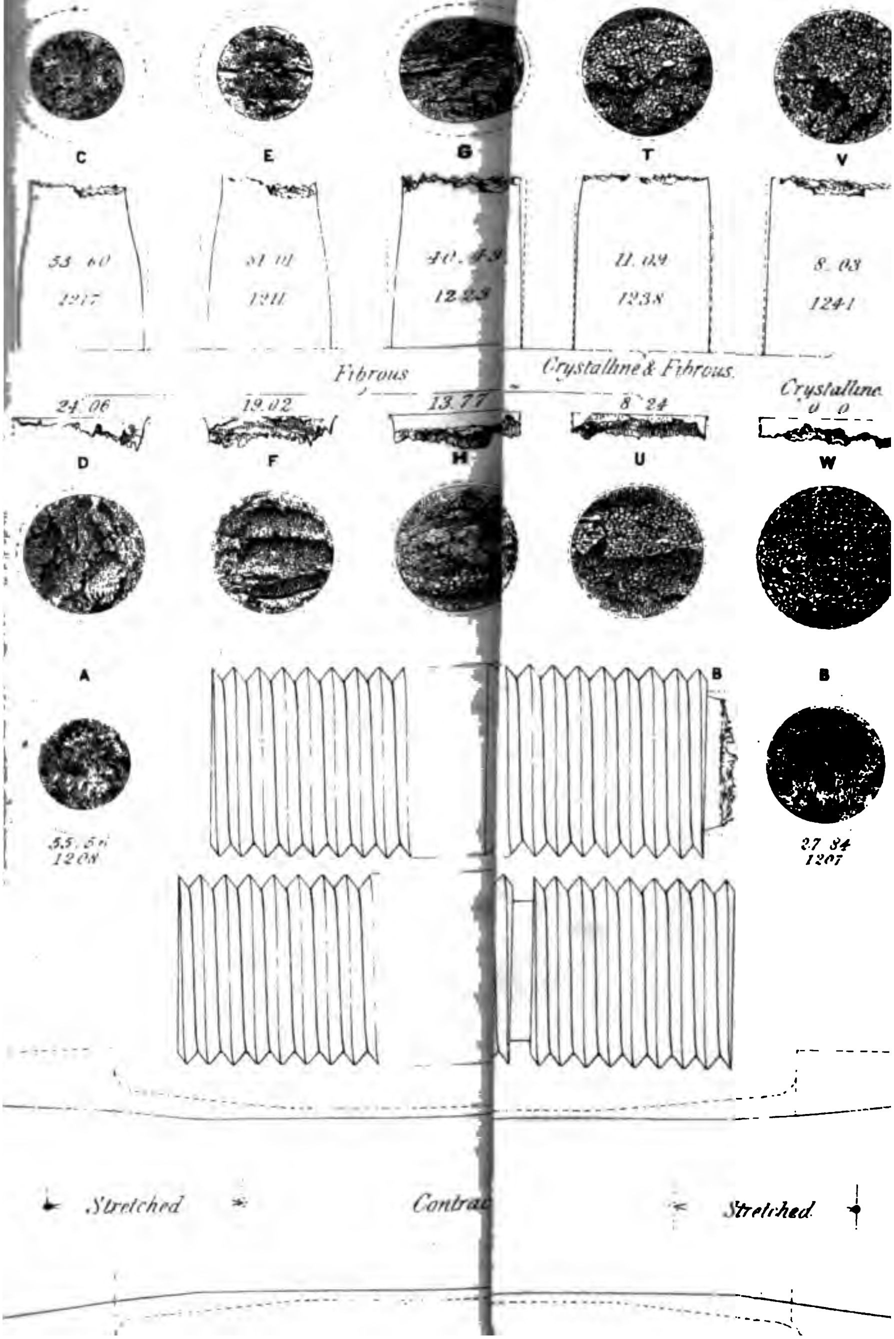

rea.
58,000
60,000
62,000
64,000
a
518
506
512
545
522
517
505
503
542
507
514
525
516
541
515
510
520

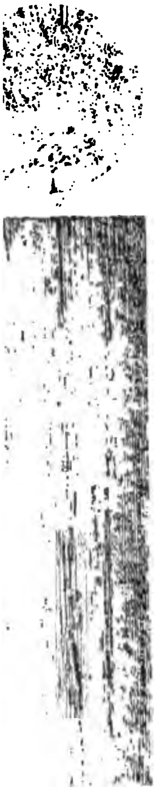
PLATE X


C
E
G
T
V
53.60
1217
51.01
1211
40.49
1223
11.09
1238
8.03
1241
Fibrous
Crystalline & Fibrous.
Crystalline
24.06
19.02
13.77
8.24
0 0
D
F
H
U
W
A
B
B
55.56
1208
27.84
1207
Stretched
Contrac
Stretched

TEXTURE DEVELOPED BY ACID.

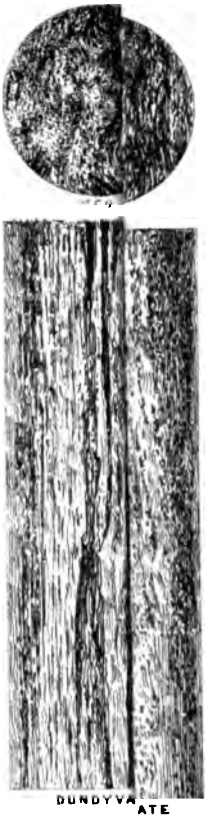
TEXTURE DEVELOPED BY ACID

Fig. 1



BOWLING

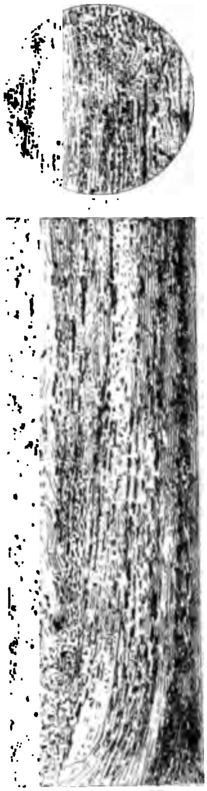
Fig. 2



DUNDYVAN PLATE

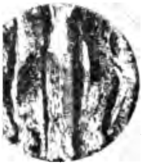
ROLLED IRON

Fig. 3



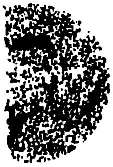
CRANK SHAFT

HAMMERED-IRON



A

B



E

F

J.K.